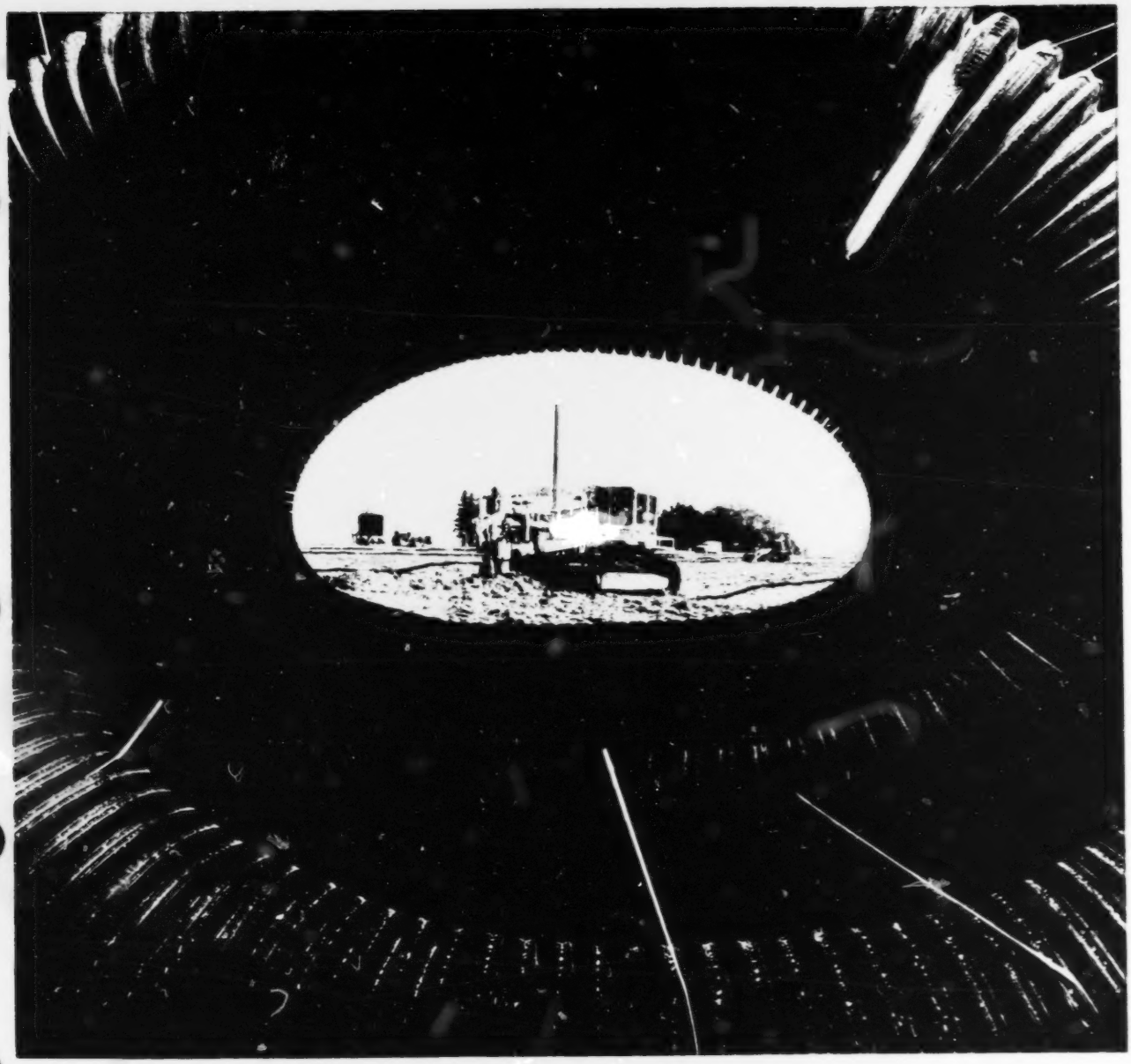

DRAINAGE GUIDE FOR ONTARIO

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DRAINAGE GUIDE
for
ONTARIO

This publication was prepared by:

R.W. Irwin — School of Engineering
Ontario Agricultural College
University of Guelph
Guelph, Ontario N1G 2W1

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SUBSURFACE DRAINAGE

1.0 GENERAL

1.1 Purpose

1.1.1 This guide is for agricultural engineering specialists, drainage engineers, drainage superintendents, drainage contractors and others interested in the planning, design and proper construction of agricultural drainage systems, and/or as a basis for writing detailed specifications.

The publication should also be useful to landowners and farm operators who desire a better understanding of drainage system design and construction technology.

1.1.2 Recommendations are general in nature, intended to serve as guidelines for designers of subsurface drainage systems that are specific for the province of Ontario.

They do not eliminate the necessity of making further on-site enquiries into such subjects as soil conditions, crops to be grown, and economics of investment. Modifications may be required to adapt the recommendation to local conditions and current or future tillage practices.

1.1.3 The material is based on the assumption that adequate outlets exist or can be provided.

1.1.4 As better information becomes available, this material will be revised.

1.2 Investment

1.2.1 Drainage is the removal of excess water from the soil surface and from the soil profile. Surface drainage removes water from the soil surface but does not lower the water table in the soil profile. However, surface drainage should always be practiced prior to making an investment in subsurface drainage.

Subsurface drains are used to lower the water table in the soil to provide a suitable environment for plants to survive and grow.

1.2.2 *Drainage is an investment* that must produce sufficient increased returns within a reasonable period of time. The longer the period of satisfactory operation, the greater the returns. To ensure that a drainage system will function properly for a long period of time (particularly in fine-textured soils), *good soil management practices must be followed.* These include the return of crop residue to the soil and may include the growing of deep-rooted legumes in a rotation.

Continuous cash cropping often creates a denser soil layer which reduces the efficiency of subsurface drains. Maintaining and building organic matter in the soil improves soil structure and keeps the soil permeable so excess water can readily reach the drain.

1.3 Land Smoothing

1.3.1 Many flat, fine-textured soils have small, shallow depressions. Ponding of surface water often occurs in these depressions for prolonged periods. This can be detrimental to growing crops. *Land smoothing to fill these slight depressions will improve surface drainage.* Shallow surface ditches bordering fields will also help remove excess surface water. Surface inlets to subsurface drains may be used to drain depressional areas.

1.3.2 Where uniformly sloped land has minor depressions land smoothing will reduce surface ponding and provide for more uniform water entry into the soil.

1.4 Surface Drainage

1.4.1 Surface drainage removes surface ponded water by means of shallow ditches that can be crossed with farm equipment. This type of drainage is adapted to flat land and where the subsoil is fine textured and dense, such as the S1 soil class. Surface drainage has little effect on soil trafficability for seed bed preparation, since it does not reduce the wetness of the soil profile.

1.4.2 Surface drainage is often the most economical method to remove surplus water. Surface drainage should also be used along with subsurface drains to provide a more efficient drainage system. (See OMAF Factsheet, *Surface Drainage*, Agdex 554.)

The surface drainage system reduces the volume of water that would ordinarily have to percolate into the soil. It reduces the volume of water that the subsurface drains must discharge, making the entire system more efficient.

1.5 Subirrigation

1.5.1 In areas where the land slope is uniform, 0.1% or less and an adequate supply of good quality water exists, the designer may consider the feasibility of combining a subirrigation design with the drainage design. If the owner wishes to use such a combined system, professional advice should be sought to determine the proper lateral drain spacing and depth of lateral drain which will produce the required watertable control.

1.6 Organic Soils

1.6.1 *No general recommendations for the drainage of organic (muck type) soils are made here.* Each case requires consideration and the advice of someone experienced in the design of drainage systems for organic soils. Special problems peculiar to organic soils involve initial soil consolidation, water table control, dike construction, seepage, pumping, etc. Drainage of shallow muck soils (450 mm or less) over sand or impermeable clay, should be avoided. The life of these organic soils is short and subsurface drainage is usually not an economic investment. (See OMAF Factsheet, *Management of Organic Soils*, Agdex 512.)

1.7 Mineral Soils

1.7.1 Mineral soils form the majority of agricultural land. Recommendations in this manual deal with the drainage of mineral soil.

1.7.2 The presence of marl, which is not a soil, or a layered bedrock at shallow depth, often makes the installation of subsurface drains inadvisable.

2.0 PLANNING AND DESIGN

2.1 How to Use this Guide

2.1.1 This guide is a basic information document prepared as a reference text related to problems encountered and decisions to be made concerning the drainage of agricultural mineral soils.

2.1.2. The design and construction of agricultural drains must be based on adequate land use, topographic surveys and soil investigations.

2.2 Soil Survey Maps

2.2.1 Drainage practices can be linked to the soil profile characteristics of which structure, texture, depth, stoniness and wetness are the most relevant. These characteristics form the basis of a survey in which soils are classified into soil series units and mapped by the Ontario Soil Survey. The coverage by maps and their accompanying reports provide useful information for drainage purposes.

2.2.2 Soil reports for most counties are available in local Public Libraries. (Unpublished soil maps may be seen in the county or district agricultural office.)

2.2.3 In general terms soil maps and reports can be used to answer: (a) what are the nature and properties of the soils at a given location?; and (b) what is the suitability of a given location for a particular agricultural use?

Note, that some small areas of wet soils cannot be shown on maps at the scale commonly used for soil surveys. A detailed on-site soil survey may be required.

2.2.4 Find the location of the farm on the soil map.

2.2.5 Write the soil map notation(s) on a separate sheet of paper.

2.2.6 Refer to the soil map legend to determine the meaning of each symbol in the notation(s).

2.2.7 Determine the soil series by referring to the expanded map legend.

2.2.8 Consult the table of contents in the soil report and find the section(s) describing the soil series noted in 2.2.7 above. Read these sections for detailed land use and soil technical information.

2.2.9 Consult Table I for a drainage recommendation.

2.2.10 How to use Table I

Note: Ontario has a wide variety of soils, and each differs in some way from all the others. Drainage needs and opportunities also vary with each soil.

The soil series in Ontario are divided into major soil groups, according to drainage needs, based on existing soil maps. However, as the program of soil mapping continues, in the light of modern concepts in soil classification, some recorrelation is necessary on the older soil maps. Revisions will be made as this recorrelation progresses. It must be kept in mind that minor variations in soil will occur within farms and must be taken into consideration. See 2.2.3.

2.3 Suitability of Location for Use

2.3.1. Study the present and future land use to determine the physical aspects essential for the proper and/or optimal operation of drains. The need for improved drainage is usually in the soil report.

2.3.2 Verify your conclusion(s) by inspecting the site in the field.

2.4 What are the Drainage Recommendations?

2.4.1 Enter Table I with the soil series name determined in 2.2.7 and get the "Drainage Design Code".

2.4.2 Enter Table II with the first two symbols of the Drainage Design Code from Table I to get recommendations for the design of a subsurface drainage system.

2.5 Drainage Design Code

Two broad classes of soil-water problems are recognized in this Guide. Groundwater soils and surface water soils. Groundwater soils are generally permeable and water logging results from rising groundwater. The major design criteria is the mid-spacing watertable elevation as determined by crop requirements and the drainage rate. The steady-state drain spacing equation in Appendix B is useful in such a design. Often the limitation in lowering the watertable in these soils is the available depth of the outfall.

Surface water soils have relatively impermeable subsoils and vertical movement of water is restricted; the hydraulic conductivity is low; and gravity drainage is restricted to water movement in soil cracks and fissures. Water movement ceases when the soil peds swell. Most water movement occurs in the cultivated surface layers. Secondary drainage treatment is often needed in these soils.

The soils listed in Table I are grouped according to the soil characteristics that are most relevant to the design of subsurface drainage systems. The two primary characteristics are the rate at which water will move through the soil profile and the degree of wetness before subsurface drains are installed, that is, the natural drainage. Two other important characteristics are the soil profile depth and the topographic position and slope.

For purposes of the Guide, each of the soil series found in Ontario has been correlated with a Drainage Design Code (Table I). Depth and spacing recommendations for each soil series can be obtained from Table II by using the Drainage Design Code.

Some of the soil information is based on test data. Most of the material is extrapolated or estimated from test results or from field experience. Local conditions and experience may indicate that deviations from these recommendations are not only desirable but necessary.

2.5.1 The Drainage Design Code* contains 5 symbols: i.e. S3WU8

first — a capital letter which defines the source of the excess water (Table A 1).
- S — surface water gley soils are those profiles that present drainage problems related to excess surface water. These soils have a distinct horizon of low permeability within one metre of the soil surface.
- G — groundwater gley soils are those profiles that present drainage problems due to the groundwater being close to the soil surface.

second — a numeral ordering of the drainage characteristic of the soil (Table A 2).

third — a capital letter representing the natural drainage class, an important factor in determining capability and versatility of land for crop production (Table A 3).

fourth — a capital, or small, letter which is an indication of the slope or landform class. Landform is significant in evaluating suitability for cultivation and drainage system layout (Table A 4).

fifth — a number which represents the topography slope class (Table A 5).

** See Appendix A for a detailed description and definition.*

2.5.2 (See Figure A-1)

S1 soils are difficult to drain. The surface is fine-textured, and the lower layers are blocky or massive which inhibit rapid water movement. The soil density increases with depth and the hydraulic conductivity is a very low value. Subsurface drains have been installed in few soils in the poorly drained class. However, these rely on soil cracking and porosity aids, such as deep tillage and mole drainage, to make them successful. Surface drainage is the best management practice.

S2 soils are somewhat coarser in texture than S1 soils and drain better. A finer textured B horizon varies from 600 to 900 mm in depth and will inhibit drainage. Subsurface drainage is quite common in this class. Poorly drained soils are most commonly drained, however, extensive areas of imperfectly and well-drained soils also have subsurface drains. Drains should not be deep and should be placed in the B horizon for best results.

S3 soils are similar to S2 soils inasmuch as a saturated zone occurs at shallow depth due to a perched watertable. The A and B soil horizons are coarser in texture. Better soil structure favors subsurface drainage. Drains should be located in the B horizon, above the dense C horizon. S3 soils represent less than 10% of Ontario soils. Subsurface drainage is largely in the imperfectly drained members, with some in the poorly and well-drained members.

S4 soils have a coarse textured surface with good soil structure, and similar qualities for the C horizon. These soils create drainage problems due to the fine textured impermeable B horizon which usually occurs at 300 mm depth. Drainage pipe placed in the parent material may not receive any drainage water due to this dense layer except where a tile trench has disrupted the internal drainage. Soil management will include good surface drainage and a program of deep tillage to break up the B horizon, if the profile permits. There are not many S4 soils in Ontario.

S5 soils have an organic layer of varying depth over sand, or over clay. Before artificial drainage of such soils it is very important to survey the depth of the organic soil. Organic soil over sand is unlikely to drain satisfactorily. Organic soils over clay will consolidate when drained and should be at least one metre in depth before drainage is even considered. S5 soils are a special problem requiring special considerations. Iron ochre is often a problem in these soils.

S6 soils are usually medium to coarse grained over bedrock at shallow depth. The feasibility of subsurface drainage depends on a detailed soil survey to ensure there is sufficient depth of cover for the drains. Since these soils have so much variation the Guide does not give information on the depth and spacing of drains. Each case must be considered on its merits.

G1 soils represent a large area in Ontario, one-fifth of the drainage activity is in this soil. In terms of soil texture and soil structure all groundwater soils drain readily; however, the differences are in the depth of the soil and whether the cause of the wetness is due to a regional or local watertable. The majority of the G1 soils are classed as well-drained. The soil profile tends to be a medium texture which does not vary greatly with depth. The G1 and S3 soil profiles are similar inasmuch as wetness is from a perched watertable on the C horizon. Less than 1 m for the S3 and over 1 m for the G1. The hydraulic conductivities are different, the G1 being twice as high.

G2 soils develop wetness from the regional watertable, with a summer groundwater at 3 m depth which will create a persistent supply of water in the spring. These soils tend to be coarse-textured and do not represent a very substantial area of drainage activity. Drains should be deep in these soils.

G3 soils also develop wetness from a regional watertable, but at a greater summer depth of 12 m or more. About 15 percent of Ontario soils are in this class with drainage activity being spread over each natural drainage class. Drains should be placed deep in the C horizon to intercept the rising groundwater. These soils are usually coarse grained to gravel.

TABLE I — ONTARIO SOIL SERIES AND RELATED DRAINAGE DESIGN CODE***

Soil Series	Family	Drainage Design Code	C.L.I. Class With Drainage	C.L.I. Class Without Drainage	Hydrologic Soil Group
Alberton	Alberton	S1I O2	3 i/w	5	D
Allendale*	Allendale	S3PA2	3 w	5	C
Alliston*	Alliston	G3IA2	-	-	B
Almonte	Haileybury	S1WK7	-	-	C
Ameliasburg	Ameliasburg	S6WV8	-	-	D
Ancaster	Honeywood	S3WU8	-	-	B
Appleton	Evanturel	G1WY9	-	-	B
Atherley	Lincoln	S1PA2	3 w	5	D
Ayr	Ayr	G3PA2	3 w/i	5	C
Bainsville	Bainsville	S3PA2	2 w	5	C
Balderson	London	G1IP2	-	-	B
Bamford	Brisbane	G3IF2	-	-	B
Bancroft	Wendigo	G3WX8	-	-	A
Bass	Renfrew	S1IH2	-	-	D
Battersea	Perth	S2Ib5	-	-	C
Bearbrook	Lincoln	S1PA2	3 w/d	5	D
Belmeade	Belmeade	S5VA1	4 d/w	5	D
Bennington	Honeywood	S3WU8	-	-	B
Berriedale	Berriedale	G2WX8	-	-	A
Berrien	Berrien	S3IM5	-	-	C
Beverly*	Beverly	S2IL4	-	-	C
Binbrook	Beverly	S2IL4	-	-	C
Blackwell	Minesing	S1PB1	2 w	4	D
Bolingbroke	Tioga	G3WK5	-	-	A
Bondhead*	Guelph	G1WU8	-	-	B
Bookton	Bookton	S3WK6	-	-	B
Boomer	**	S4WB2	3 i/m	5	B
Brady*	Brady	G2IJ5	-	-	B
Brant*	Honeywood	S3WU8	-	-	B
Brantford	Brantford	S2WU7	-	-	C
Bridgman	Eastport	G3WV9	-	-	A
Brighton	Fox	G2WN7	-	-	A
Brisbane*	Brisbane	G3IF2	-	-	B
Brockport	Lockport	S6MY9	-	-	B
Brooke	Brooke	S6PG3	-	-	C
Brookston	Brookston	S2PA2	2 w	5	D
Bucke	Bucke	S3WX8	-	-	B
Burford*	Burford	G3WQ4	-	-	A
Burnbrae	Farmington	S6WG3	-	-	B
Burnstown*	Vasey	G1WV9	-	-	B
Burpee	Burpee	G3PA1	5 w	6	C
Buzwah*	Haileybury	S1WK7	-	-	C
Caistor	Haldimand	S2IP5	-	-	C
Caledon	Burford	G3WQ4	-	-	A
Camilla	Brisbane	G3IF2	-	-	B
Campbell*	Haileybury	S1WK7	-	-	C
Cane*	Cane	S2PA1	2 w	5	D
Carp*	Perth	S2Ib5	-	-	C
Casey	Earlton	S4IO6	-	-	B
Cashel	Huron	S2MU6	-	-	C
Castor*	Nipissing	S3IO3	-	-	C
Chesley	Brookston	S2PA2	2 w	5	D
Chinguacousy*	Haldimand	S2IP5	-	-	C
Christy	Moose	G1PA1	6 w/p	6	C
Clyde	Clyde	S1PA1	2 w	5	D
Codrington	Tuscola	S3IC4	-	-	C
Colborne	Burford	G3WQ4	-	-	A
Colwood*	Colwood	G1PB2	2 w	5	C
Conestoga	**	G1IO4	-	-	B
Conover	**	S2IO4	-	-	C
Cooksville	Trafalgar	S6IO4	-	-	B
Craigleith	Elderslie	S2IP4	-	-	C
Cramahe	Sargent	G3WT8	-	-	A
Crombie	Colwood	G1PB2	2 w	5	C
Dalton	Mountain	S3IK4	-	-	C
Darlington	Guelph	G1WU8	-	-	B
Deloro*	Osprey	G1WV8	-	-	B
Donald	**	G3IB2	3 i	5	B
Donnybrook	Dumfries	G3WV8	-	-	A
Dorking	**	S2PA1	4 d/w	5	D
Dumfries*	Dumfries	G3WV8	-	-	A
Dummer*	Osprey	G1WV8	-	-	B
Dundonald	Bookton	S3WK6	-	-	B
Dunedin	Saugeen	S2WX8	-	-	C
Eamer	Grenville	G1WX7	-	-	B
Earlton*	Earlton	S4IO6	-	-	B
Eastport	Eastport	G3WV9	-	-	A
Edenvale	Berrien	S3IM5	-	-	C
Eganville*	Guelph	G1WU8	-	-	B
Elderslie	Elderslie	S2IP4	-	-	C
Eldorado	Guelph	G1WU8	-	-	B
Ellwood	Perth	S2IB5	-	-	C
Elmbrook	Haldimand	S2IP5	-	-	C
Elmira	**	G2PA1	4 w/i	5	C
Elmsley	Farmington	S6WG3	-	-	B
Embro	Tuscola	S3IC4	-	-	C
Emily*	Matilda	G1IM4	-	-	B
Englehart	Allendale	S3PA2	4 w	5	C
Evanturel*	Evanturel	S4WY9	-	-	B
Farmington	Farmington	S6WG3	-	-	B
Ferndale	Brookston	S2PA2	2 w	5	D
Flamboro*	Granby	G3PE2	4 w	5	C
Floradale	**	G3IE3	-	-	B
Font	**	G3WV9	-	-	A
Fonthill	Burford	G3WQ4	-	-	A
Fox*	Fox	G2WN7	-	-	A
Foxboro	Colwood	G1PB2	2 w	5	C
Franktown	Franktown	S6IA3	-	-	B
Freeport	**	G1WV6	-	-	B
Galesburg	Vasey	G1WV9	-	-	B
Gananoque*	Haileybury	S1WK7	-	-	C
Gerow	Gerow	S6PA1	-	-	C
Gilford	**	G3PE2	4 w	5	C
Gobles	Perth	S2IU7			C
Gordon*	Renfrew	S1IH2	-	-	D
Granby	Granby	G2PE2	3 w	5	C
Grand	**	G1Wa1	2 i	4	B
Grenville*	Grenville	G1WX7	-	-	B
Grimsby*	Fox	G2WN7	-	-	A
Guelph*	Guelph	G1WU8	-	-	B
Guerin*	London	G1IP2	-	-	B
Gwillimbury	Gwillimbury	G3IO4	-	-	B
Haldimand	Haldimand	S1IP5	-	-	C
Hampden	-	S5IA2			D
Harkaway*	Otonabee	G1WX7	-	-	B
Harriston	Guelph	G1WU8	-	-	B
Harrow	Pontypool	G3WW9	-	-	A
Havelock	Pontypool	G3WW9	-	-	A
Hawkesville	**	G3PA1	4 w/i	5	C
Haysville	**	G3IB2	3 i	4	B
Heidelberg	**	G3II4	-	-	B
Hendrie	Hendrie	G3IA2	-	-	B
Hespeler	Granby	G3PA2	4 w/i	5	C
Hillier	Ameliasburg	S6WV8	-	-	B
Hillsburgh	Pontypool	G3WW9	-	-	A

TABLE I — ONTARIO SOIL SERIES AND RELATED DRAINAGE DESIGN CODE***

Soil Series	Family	Drainage Design Code	C.L.I. Class With Drainage	C.L.I. Class Without Drainage	Hydrologic Soil Group
Hinchinbrooke*	Colwood	G1PB2	2 w	5	C
Honeywood	Honeywood	S3WU8	-	-	B
Howland*	Howland	G1IO5	-	-	B
Huron	Huron	S2MU6	-	-	C
Innisville	Lyons	G1PD1	4 w	5	C
Jeddo	Lincoln	S1PA2	4 w/d	5	D
Kagawong	Ameliasburg	S6WV8	-	-	B
Kars	Burford	G3WQ4	-	-	A
Kelvin	Brookston	S2PA2			D
Kemble*	Elderslie	S2PI4	-	-	C
Kenabeek	Kenabeek	G2PA3	6 w	6	C
Killean	Killean	S1IO2	-	-	B
King	Brantford	S2WU7	-	-	C
Kirkland	**	G3WB2	3 i/m	5	A
Kossuth	**	G1IO4	-	-	B
L'Achigan	Rubicon	G2IK5	-	-	B
Lambton	Tuscola	S3IM5	-	-	C
Lanark	Perth	S2Ib5	-	-	C
Landsdowne*	Renfrew	S1IH2	-	-	D
Leech*	Renfrew	S1IH2	-	-	D
Leith	Honeywood	S3WU8	-	-	B
Leithrim	Farmington	S6WG3	-	-	B
Lily	Lyons	G1PD1	6 w/p	6	C
Lincoln	Lincoln	S1PA2	4 w/d	5	D
Lindsay*	Brookston	S2PA2	2 w	5	D
Lisbon	**	G3WV8	-	-	A
Listowel	London	G1IP2	-	-	B
Little Current	Ameliasburg	S6WV8	-	-	B
Lockport	Lockport	S6MY9	-	-	B
London*	London	G1IP2	-	-	B
Lonsdale	-	S5VA2			D
Lovering	Haldimand	S2IP5	-	-	C
Lowbanks	Lowbanks	G1VA2			B
Lyons*	Lyons	G1PD1	3 w	5	C
Macton	**	G1IB2	3 i	5	B
Magnetawan	Magnetawan	G1PR4	-	-	C
Mallard*	Rubicon	G2IK5	-	-	B
Malton	Brookston	S2PA2	2 w	5	D
Mannheim	**	G1WS6	-	-	B
Manotick	Bucke	S3WX8	-	-	B
Maplewood	**	S3PB2	2 w	5	C
Marionville	Bainsville	S3PA2	2 w	5	C
Marsh	**	S5VA1	-	-	D
Maryhill	**	G1PA2	2 w	4	C
Matilda	Matilda	G1IM4	-	-	B
Matson	Tuscola	S3IC4	-	-	C
Medonte	South Bay	S1WO5	-	-	C
Miami	**	S2WX7	-	-	C
Mill	Wauseon	S3PA1	3 w	5	C
Milliken	London	G1IP2	-	-	B
Minesing	Minesing	S1PB1	2 w	5	D
Mississauga	Lincoln	S1PA2	5 w/r	6	D
Monaghan	Beverly	S2IL4	-	-	C
Monteagle*	Wabi	G1WT6	-	-	B
Morley	Brookston	S2PA2	3 d/w	5	D
Morrisburg	Elderslie	S2IP4	-	-	C
Moscow*	Brookston	S2PA2	2 w	5	D
Mountain	Mountain	S3IK4	-	-	C
Muck	**	S5VA1	-	-	D
Muriel	Huron	S2MU7			C
Murray	Tuscola	S3IC4	-	-	C
Napanee*	New Liskeard	S1PA1	3 d/w	5	D
Nelson	Huron	S2MU6	-	-	C
Newburgh	Honeywood	S3WU8	-	-	B
Newcastle	Honeywood	S3WU8	-	-	B
Niagara	Haldimand	S2IP5	-	-	C
Nipissing	Nipissing	S3IO3	-	-	C
Norham	Honeywood	S3WU8	-	-	B
Normandale	Heidelberg	G1IH5			B
North Gower*	Brookston	S2PA2	2 w	5	D
Oakland	Camilla	G3IF3			B
Oakview	-	S5VA2			D
Oneida	South Bay	S1WO5	-	-	C
Ontario	**	S2WK4	-	-	C
Osgoode	Colwood	S2PB2	2 w	5	C
Oshtemo	Fox	G2WN7	-	-	A
Osnabruck	Brookston	S2PA2	4 w/p	5	D
Osprey	Osprey	G1WV8	-	-	B
Otonabee*	Otonabee	G1WX7	-	-	B
Otterskin	Mountain	S3PK4	-	-	C
Parkhill*	Lyons	G1PD1	2 w	5	C
Peat	**	S5VA1	6 w	6	D
Peel	Perth	S2Ib5	-	-	C
Pelham	**	G3WX9	-	-	A
Perch	New Liskeard	S1PA1	4 d/w	5	D
Percy	Honeywood	S3WU8	-	-	B
Perth	Perth	S2Ib5	-	-	C
Petherwick	Colwood	G1PB2	2 w	5	C
Phipps*	New Liskeard	S1PA1	3 w	5	D
Piccadilly	Tuscola	S3IC4	-	-	D
Pike	Haileybury	S1WK7	-	-	C
Pike Lake	Dumfries	G3WV8	-	-	A
Plainfield	Eastport	G3WV9	-	-	A
Pontypool	Pontypool	G3WW9	-	-	A
Preston	**	G3IG3	4 i/r	6	B
Renfrew	Renfrew	S1IH2	-	-	D
Rideau	Rideau	S1IO2	-	-	D
Rubicon*	Rubicon	G2IK5	-	-	B
Sargent	Sargent	G3WT8	-	-	A
Saugeen	Saugeen	S2WX8	-	-	C
Schomberg	Huron	S2MU6	-	-	C
Scotland	Caledon	G3WM7			A
Seely's Bay	Huron	S2MU6	-	-	C
Senaca	Guelph	G1WO7			B
Shashawandah	Shashawandah	S6WK4	-	-	B
Sidney*	Lincoln	S1PA2	3 w	5	D
Silver Hill	Silver Hill	G1PA3			B
Simcoe	Brookston	S2PA2	2 w	5	D
Smithfield	Perth	S2Ib5	-	-	C
Smithville	Brantford	S2WU7	-	-	C
Snedden	Renfrew	S1IH2	-	-	D
Solmesville	Perth	S2Ib5	-	-	C
South Bay	South Bay	S1WO5	-	-	C
Springvale	**	G3MK6	-	-	A
St. Clements	**	S2WK6	-	-	C
St. Jacobs	**	G3WG2	-	-	A
St. Peter	St. Peter	G3WA3	-	-	A
Ste. Rosalie	Lincoln	S1PA2	3 w/d	5	D
St. Samuel*	Kenabeek	G2PA3	6 w	6	C
St. Thomas	Wendigo	G3WX8	-	-	A
St. Williams	St. Williams	G1PA2			B
Stafford	London	G1IP2	-	-	B
Stockdale	Colwood	G1PB2	2 w	5	C
Styx	-	G1VA2			B

TABLE I — ONTARIO SOIL SERIES AND RELATED DRAINAGE DESIGN CODE***

Soil Series	Family	Drainage Design Code	C.L.I. Class With Drainage	C.L.I. Class Without Drainage	Hydrologic Soil Group	Soil Series	Family	Drainage Design Code	C.L.I. Class With Drainage	C.L.I. Class Without Drainage	Hydrologic Soil Group
Sullivan	Sullivan	G3WA4	-	-	A	Waterloo	Pontypool	G3WW9	-	-	A
Tansley	Perth	S2Ib5	-	-	C	Watford	Pontypool	G3WH7		-	A
Tavistock	Tuscola	S3IC4	-	-	C	Watrin	Granby	G3PE2	6 w	6	C
Tecumseh	Brady	G2IJ5	-	-	B	Waupoos	Huron	S2MU6	-	-	C
Teeswater	Honeywood	S3WU8	-	-	B	Wauseon	Wauseon	S3PA1	3 w	5	C
Tennyson*	Vasey	G1WU8	-	-	B	Wayside	Alliston	G3IA2	-	-	B
Thames	Perth	S2Ib5	-	-	C	Welland	Lincoln	S1PA2	4 w/d	5	D
Thorah	Kenabeek	G2PA3	6 w	6	C	Wellesley	**	S2ID2	-	-	C
Thwaites	Evantural	G1WY9	-	-	B	Wemyss	Coutts	G1IK4	-	-	B
Tioga*	Tioga	G3WK5	-	-	A	Wendigo*	Wendigo	G3WX8	-	-	A
Toledo*	Brookston	S2PA2	2 w	5	D	Wendover	Rideau	S1IH2	-	-	D
Trafalgar	Trafalgar	S6IO4	-	-	B	Westmeath	Tioga	G3WK5	-	-	A
Trent	Tuscola	S3IC4	-	-	C	Whitby	London	G1IP2	-	-	B
Tuscola*	Tuscola	S3IC4	-	-	C	White Lake*	Tioga	G3WK5			A
Tweed	Tweed	S6WV8	-	-	B	Whitfield	Honeywood	S6WU8	-	-	B
Uplands	Wendigo	G2WX8	-	-	A	Wiarton	Matilda	G1IM4	-	-	B
Vanessa	Ayr	G3PA2			C	Wilmot	**	S2PA2	2 w	5	D
Vars	Guelph	G1WU8	-	-	B	Wilsonville	Dumfries	G3WI7			A
Vasey*	Vasey	G1WV9	-	-	B	Winona	Berrien	S3IM5	-	-	C
Vincent	Saugeen	S2WX8	-	-	C	Woburn	Guelph	G1WU8	-	-	B
Vineland*	Brady	G2IJ5	-	-	B	Wolford	Saugeen	S2WX8	-	-	C
Vittoria	Vittoria	S3IH4			C	Wolsey*	New Liskeard	S1PA1	2 w	5	D
Wabi	Wabi	G1WZ6	-	-	B	Wooler	Honeywood	S3WU8	-	-	B
Walshear	Walshear	S3WH6			C	Woolwich	**	G1WO4	-	-	B
Walsingham	Walsingham	G2IA2			A	Wyevale	St. Peter	G3WA3	-	-	A

* *Soil series having shallow phases over bedrock.*
The hydrologic grouping for the rocky phases of these soils should be reduced one group (ie. C reduces to B).

** *Soil family name not available if not listed.*

*** *A drainage design code has been assigned to every soil series; however, the effectiveness of drainage must be assessed on an individual site basis.*

TABLE II — GENERAL DEPTH AND SPACING RECOMMENDATIONS FOR LATERAL DRAINS

Drainage Design Code 1	Drain Depth (mm) 2	DRAIN SPACING (m) Cash Crops 3	Small Grains and Forage Crops 4	Surface Drains Needed 5	Remarks* 6
S1	600 - 650	6 - 12	10 - 15	Yes	Subsurface drainage not feasible unless soil structure well defined when subsoil is wet.
S2	600 - 700	6- 15	12 - 20	Yes	
S3	700 - 1000	9 - 15	12 - 20	Yes	Quicksand may be present.
S4	-	-	-	Yes	Shallow soil barrier layers limit drain effectiveness.
S5	Special investigation required			Yes	Water control works may be needed
S6	600	-	-	Yes	Shallow soil over bedrock limits design possibilities
G1	800 - 1000	12 -18	12 - 50		
G2	850 - 1000	14 - 18	15 - 20		Quicksand may be present.
G3	900 - 1200	12 - 18	15 - 20		Quicksand may be present.

**Fine sandy loams and sandy loam soil in Class S3, G2 and G3 require envelope protection.*

2.5.3 Land Use and Hydrologic Classes

Table I provides additional information which is of use for special engineering projects. In Ontario, published Canada Land Inventory (CLI) ratings are for soils assuming drainage in place. The CLI ratings (Table A-6) given in Column 4 are only those shown on current CLI maps where the major hazard is excess water or inundation. They correspond to application of the CLI system in which the requirement for drainage is recognized only in poorly and very poorly drained mineral soil series. Exceptions to the general rule include three well drained soil series (Boomer, Grand, Kirkland) and five imperfectly drained soil series (Alberton, Donald, Haysville, Macton, Preston). In all eight exceptions inundation by overflow from watercourses is a hazard to agriculture. In contrast, CLI ratings without drainage (Column 5) are an estimate of agricultural capability without necessary drainage works in place.

In Column 6, the Hydrologic Soil Groups are grouped according to their rate of water intake after prolonged wetting and are interpretations based upon the USDA-SCS criteria for hydrologic soil groups. The interpretation given for each soil series is derived from data of the Ontario Soil Survey for that series.

2.6 How to Use Table II

Column 1 Soil Drainage class. This column contains the first two symbols of the Drainage Design Code selected from Table I and reflects the source of the drainage water problem and the soil drainage characteristics. (See Table A-2)

Column 2 Drain Depth. This column gives a recommended range in depth to the trench bottom for lateral drains. The selected design depth should be within the range but will depend on land slope, soil profile, topography and outlet elevation.

Column 3 Drain Spacing for Cash Crops. This column gives the recommended range in lateral drain spacing when used in systematic or pattern drainage systems. The actual spacing selected will depend on the degree of drainage the farmer desires for the crops to be grown. It is often an economic decision. Since the annual investment in a cash crop is higher than in a field crop the recommended spacing is closer than in Column 4. The actual spacing is influenced by the depth of the drain, the dimensions of the field, cropping and cultivation pattern and the soil's physical properties.

Column 4 Drain Spacing for Small Grains and Forage Crops. This column gives the recommended range for lateral drain spacing when used in systematic installations. Comments for Column 3 also apply to Column 4.
Where random drains are used to drain isolated wet spots, seepage lines and springs, drain spacing is usually not a factor in the design; however, future expansion of the system should be considered.

Column 5 Surface Drainage. This column recommends that surface drains be used; (a) in conjunction with subsurface drains; or (b) where surface drainage is considered to be a feasible solution to a drainage problem.

Column 6 Remarks. This column contains additional information which may be of value in the design and construction of a subsurface drainage system.

2.6.1 When using Table II it is important to determine from the farm operator the type of cropping that will be practised (small grains and forage, or cash crops) in order to make the proper drain-spacing recommendation.

2.6.2 The depth, spacing, and location of drains are based on site conditions, including soils, topography, groundwater, and outlets. Crops to be grown and economics also must be considered in the decisions.

2.6.3 Recommendations on drain depth and drain spacing are based on research data available in Ontario and upon the long experience and practical observation of working in the field. They are subject to revision as new information becomes available.

2.6.4 The maximum spacing between parallel lateral drains recommended is 15 m. Fields seldom have sufficient uniformity in drainage characteristics or surface elevation to ensure uniformity of field drying at greater spacings, even though mathematical calculations of drain spacing infer the spacing may be greater.

2.6.5 Minimum drain spacing between parallel lateral drains is recommended as 6 m. The minimum drain spacing is an economic decision. Small depressional areas may warrant a closer drain spacing.

2.6.6 If a random or combination system is required at this time, it should be designed, if possible, to allow for more intensive drainage at a future date. This is accomplished primarily by designing main and submain drains large enough to accommodate the flow from lateral drains that might be added later.

2.6.7 If a system is to be used for subirrigation, suitable drainage and soils criteria must be developed for the design.

2.6.8 Example Problem
Determine the depth and spacing for subsurface drains to be installed on the south-half of lot 6, concession VI, Mersea township, Essex county. The crop to be grown is early potatoes.

Solution

Locate the farm on the Essex county soil map by lot and concession. The map shows that the soil is classified as Berrien sandy loam.

From Table I it is noted that the Berrien series is listed under the Drainage Design Code as S3I M5. Table II at Soil Group S3 shows that the drain depth should be 700 — 1000 mm. Since early potatoes are a cash crop, a drain spacing of 9 to 15 m will be obtained under the column "Cash Crops".

Under "Surface Drainage" it is recommended that surface drains or surface inlets be installed. The "Remarks" column shows the possibility of encountering quicksand in the deeper wet sand areas. Actual spacing will depend upon the degree of drainage the farmer desires for the crop; but for potatoes it would be closer to the maximum spacing recommended. Depth of the lateral drains depends upon local topography but the closer the spacing, the less the depth needed, probably 750 — 800 mm here.

2.6.9 Where adequate information is available on the soil profile characteristics and physical properties, spacing of lateral drains can be calculated from a theoretical equation. A popular equation is given in Appendix B which illustrates the design parameters.

2.7 How to Use Table III

2.7.1 Drainage of Special Crops
The design of subsurface drains for a number of high-value crops, mainly fruit, nursery stock, vegetables, and turf, should receive special attention. The additional cost of closer lateral drain spacing is small when compared to the value of an orchard. For this reason, special recommendations have been outlined in Table III based on row spacing rather than soil characteristics.

This group of crops is very susceptible to the injurious effects of poor drainage. For example, the depth of rooting usually determines the size and productivity of a fruit orchard. Therefore, the soil should contain little or no free water in the top 600 — 1000 mm, except for a short period after a heavy rain. This is particularly true in early spring during blossoming and fruit-setting periods.

2.7.2 When designing the layout of drains for orchards, an intercepter drain should be installed along the higher end of the orchard to intercept seepage water that might cause prolonged flow in the lateral drains. This action will deter tree roots from entering the lateral drains.

TABLE III — DEPTH AND SPACING OF LATERAL DRAINS FOR SPECIAL CROPS

Crop	Crop Row Spacing (m)	Drain Depth (mm)	Drain Spacing (m)	Remarks
1	2	3	4	5
Apples	12 × 12	750 +	12	Every row
Dwarf Apples	3 × 4	750 +	6 to 9	Every other row
Cherries, sweet	7.5 × 6	900 to 1000	7.5 to 12	Every row, or every other row
Cherries, sour	6 × 6 or 4	750 +	6 to 12	Every row, or every other row
Grapes	3	750 +	9 6	Every third row where crop established, every other row for French hybrids
Grapes	3	750 +	6 to 9	For diagonal drainage systems installed before planting, or midway between posts
Peaches	6 × 3	In sand — 1200	6 to 12	Parallel to rows — every other row Diagonal to rows — every third row
Peaches	6 × 6	Shallow sand over clay — 600 to 750 (just in clay)	6 to 12	Parallel to rows — every other row; except every other row in clay soil, sidehill seepage areas and depressional areas Diagonal to rows — every third row
Pears	6 × 6	750	6	Every other row
Vegetable crops		600 to 750	6 to 9	Open surface inlets in depressional areas may be needed
Nursery stock		600 to 750	6 to 9	
Fine turf (golf green)		400 to 450	3 to 4	
Medium turf (lawns)		450 to 600	4.5	
Sports fields and Recreation areas		450 to 700	5 to 10	Special design required

2.8 Plan of Drain

2.8.1 A plan of the subsurface drainage system should be prepared by or for the contractor to use during construction and be left with the owner as a record of the installation. This plan is also useful for recording the location of utilities. The plan should be based on elevations established by a survey.

The plan should give details regarding location, size and grade of drain and the accessories necessary for proper construction of the system.

A topographic plan, prepared by a third party, can be the basis for obtaining tenders on the cost from several drainage contractors.

2.8.2 Before Construction

.1 All construction work should follow a definite plan which has been drawn, or considered, in advance of the construction.

.2 The job site should be inspected by the contractor and owner to ensure that the work to be done is agreed upon and/or facilities and outlets on which this installation depends is satisfactory to each.

.3 Any necessary easements or permits must be obtained by the owner well in advance of construction.

.4 Buried cables, pipelines or other utilities must be identified by the owner and the public utility concerned should be requested to mark and uncover the exact location of such buried obstacles at all points where drains and the buried obstacle may intersect.

.5 *The owner should ensure that the soil will respond to underdrainage, and whether the soil contains chemicals which will adversely affect the long-term performance of the drain.*

.6 Prior to the design of the drainage system, investigations must be carried out to determine if any Utility facilities or rights-of-way will be encroached or crossed. If so, the Utility must be so advised during the design stage to approve the proposed work and to acquire Regulatory Approval, if necessary.

The Utility must again be contacted at least 48 hours prior to construction in order for the Utility to locate and stake the facilities. No work may commence until the Utility, Contractor and Owner are mutually satisfied that all requirements and safety precautions have been met.

2.8.3 After construction

1. All changes in the plan made during construction, and any hazards encountered which may affect future maintenance, should be marked on the plan.

.2 When construction is completed a plan of the work, as installed in the field, should be left with the landowner by the contractor.

.3 It is desirable that a copy of the plan be filed with the deed to the property. An aerial photograph of the completed work is also a useful record.

2.9 Outlet

2.9.1 A satisfactory outlet must be available for a proposed subsurface drainage system. Design of outlets is discussed in Section 8 of this Guide.

2.9.2 Water collected in drains must be discharged at a point where no damage to any other owner will occur.

2.9.3 Legal considerations and procedures for obtaining an outlet are found in the OMAF Factsheet, *Drainage Legislation*, Agdex 752.

2.9.4 Consideration must be given to Ontario drainage laws governing outlets. Outlet agreements should be legally registered for future protection.

2.10 Drainage Coefficient

2.10.1 The drainage coefficient is the rate at which water is to be removed from an area. It is a value selected to provide adequate drainage for future crops and is expressed in mm per 24 hours. It is used to calculate the required pipe diameter for water transport and, less frequently, to determine a drain spacing. The following coefficients are recommended for subsurface drainage in mineral soils:

.1 Under normal surface drainage conditions, and where no surface water is to be admitted directly into the subsurface drain, use:
6 mm per 24 hours for low-value forage crops,
9 mm per 24 hours for improved forage and general grain crops
12 mm per 24 hours for cash crops
20 mm per 24 hours for high-value specialized crops.
Apply the above criteria only to the wet land area to be drained. Increase the area to include any surface runoff from higher land.

.2 Where surface water is to be admitted into the subsurface drain; use the following drainage coefficients for sections of the drain down grade from the surface inlet
15 mm per 24 hours for blind inlets
25 mm per 24 hours for open inlets.
Apply the above criteria to the watershed area likely to contribute surface water to the surface inlet.
Note: In almost every case the open area into the pipe, or diameter of the drain pipe, controls the rate of flow rather than the type of inlet.

.3 This recommendation applies to all crops except high value vegetable crops which will suffer scalding from ponded surface water. For these, install surface inlets in depressional areas and provide a drainage coefficient of 35 mm per 24 hours.

2.11 Main Drain Pipe Diameter Selection

2.11.1 Definition: The term "pipe" refers to any product such as clay, shale or concrete drain tile, corrugated plastic drainage tubing, or other type of conduit, which conforms to the appropriate standards in Section 6, Materials.

2.11.2 The required diameter of a drain pipe depends upon the grade of the drain, the internal hydraulic roughness of the pipe, and the volume of water to be carried. The volume of the water depends upon the physical property of soil, the depth and spacing of the drains, and the area drained.

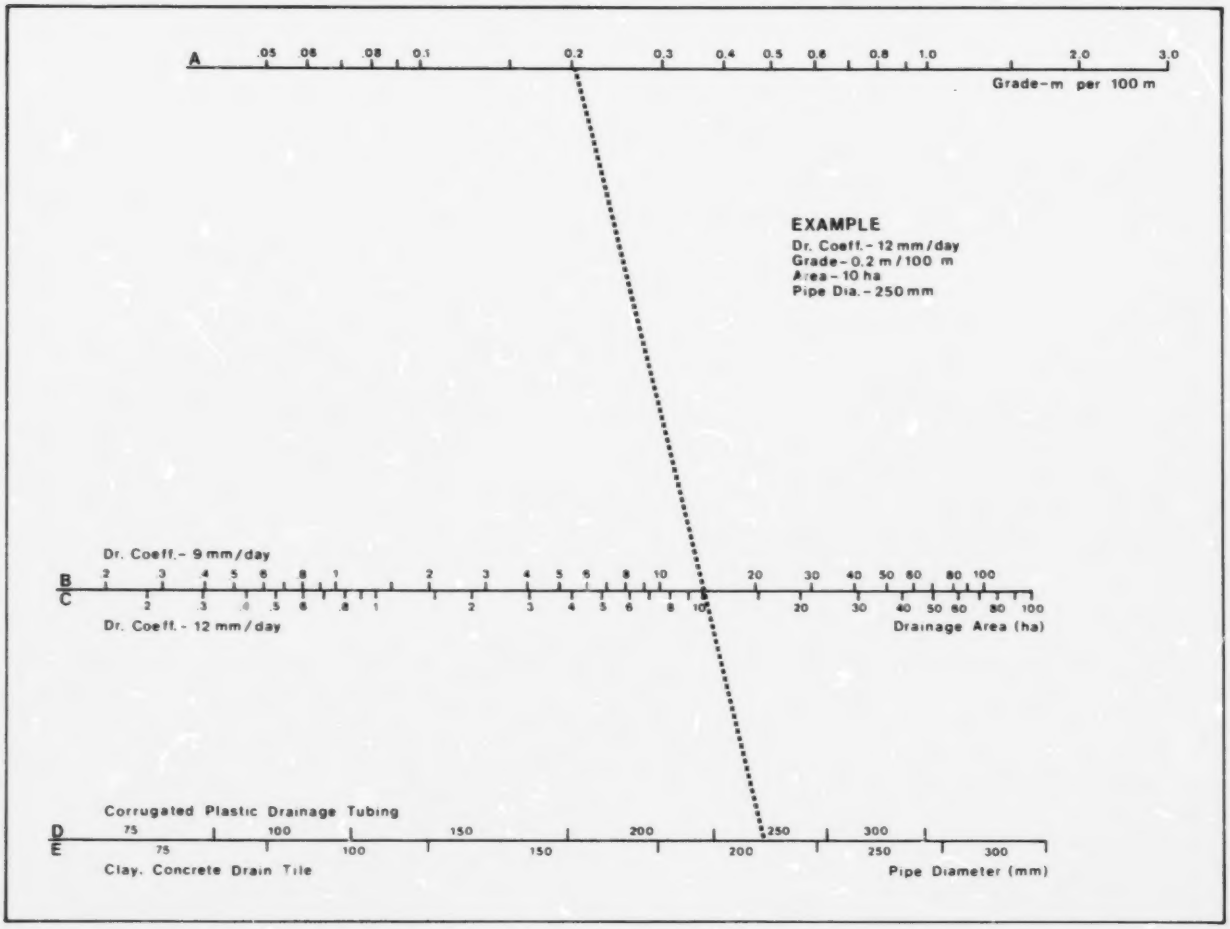
A
.05 .06 .08 0.1 0.2 0.3 0.4 0.5 0.6 0.8 1.0 2.0 3.0
Grade–m per 100 m
EXAMPLE
Dr. Coeff. – 12 mm/day
Grade – 0.2 m/100 m
Area – 10 ha
Pipe Dia. – 250 mm
Dr. Coeff. – 9 mm/day
B
C
2 3 4 5 6 8 1 2 3 4 5 6 8 10 20 30 40 50 60 80 100
Dr. Coeff. – 12 mm/day
Drainage Area (ha)
Corrugated Plastic Drainage Tubing
D
75 100 150 200 250 300
E
75 100 150 200 250 300
Clay. Concrete Drain Tile
Pipe Diameter (mm)

Figure 1. Nomograph for selection of drain size

2.11.3 When designing main and submain drains for random or combination systems, choose a pipe size that will accommodate the flow from the area as if it were drained systematically. This will permit more intensive drainage in the future.

2.11.4 Two methods for obtaining drain pipe diameter are presented in this Guide. The choice of method is left to the user.

The required diameter can be selected directly from Figure 1. Knowing the proposed drain grade (A) and the area to be drained corresponding to a preselected drainage coefficient (B or C), join these points with a straight edge and read off the required pipe size, (D) if corrugated plastic drainage tubing is used, or (E) if well-laid clay or concrete drain tile is used.

For example, a main drain on a grade of 0.2% (0.2 m per 100 m) used as an outlet for 10 ha of land at a drainage coefficient of 12 mm per 24 hours will require 250 mm diameter corrugated plastic drainage tubing (D), **or,** 200 mm diameter clay or concrete drain tile (E).

Solutions may also be obtained from Figure 1 for drainage coefficients other than those shown. For example, if the selected coefficient is 25 mm per 24 hours (about double the 12 mm per 24 hours coefficient used above), simply double the drainage area to 20 hectares, and use a straight edge from 0.2 on (A) through 20 hectares on (C) and read the required drain diameter in (D) **or** (E). Solutions for other drainage coefficients can be obtained in the same way.

2.11.5 An alternative method for selecting the proper diameter of main drain provides additional information on pipe velocity and discharge which may be useful in the design.

Note: This method must be used for large diameter pipe and areas not included in Figure 1.

Enter Figure 2 using the drainage area, in hectares, and move vertically to the diagonal line representing the appropriate drainage coefficient. Move horizontally to the left to obtain the drain discharge, L/s.

Enter the left side of Figure 3 for corrugated plastic drainage pipe, or Figure 4 for concrete or clay drain tile using the drain discharge from Figure 2; move horizontally to the right until you intersect the vertical line indicating the grade of the drain. This intersection determines the diameter of the pipe and the flow velocity in the drain when running full.

For example, a main drain on a grade of 0.2% (0.2 m per 100 m) is used as an outlet for 15 hectares of land at a drainage coefficient of 12 mm per 24 h. From Figure 2 the discharge is 20 L/s. By entering Figure 3 at 20 L/s and moving to the right to the grade 0.2, the required diameter of corrugated plastic drainage tubing is 300 mm. Similarly, entering Figure 4 at 20 L/s and moving to the right to 0.2 the required diameter of clay or concrete pipe is 250 mm.

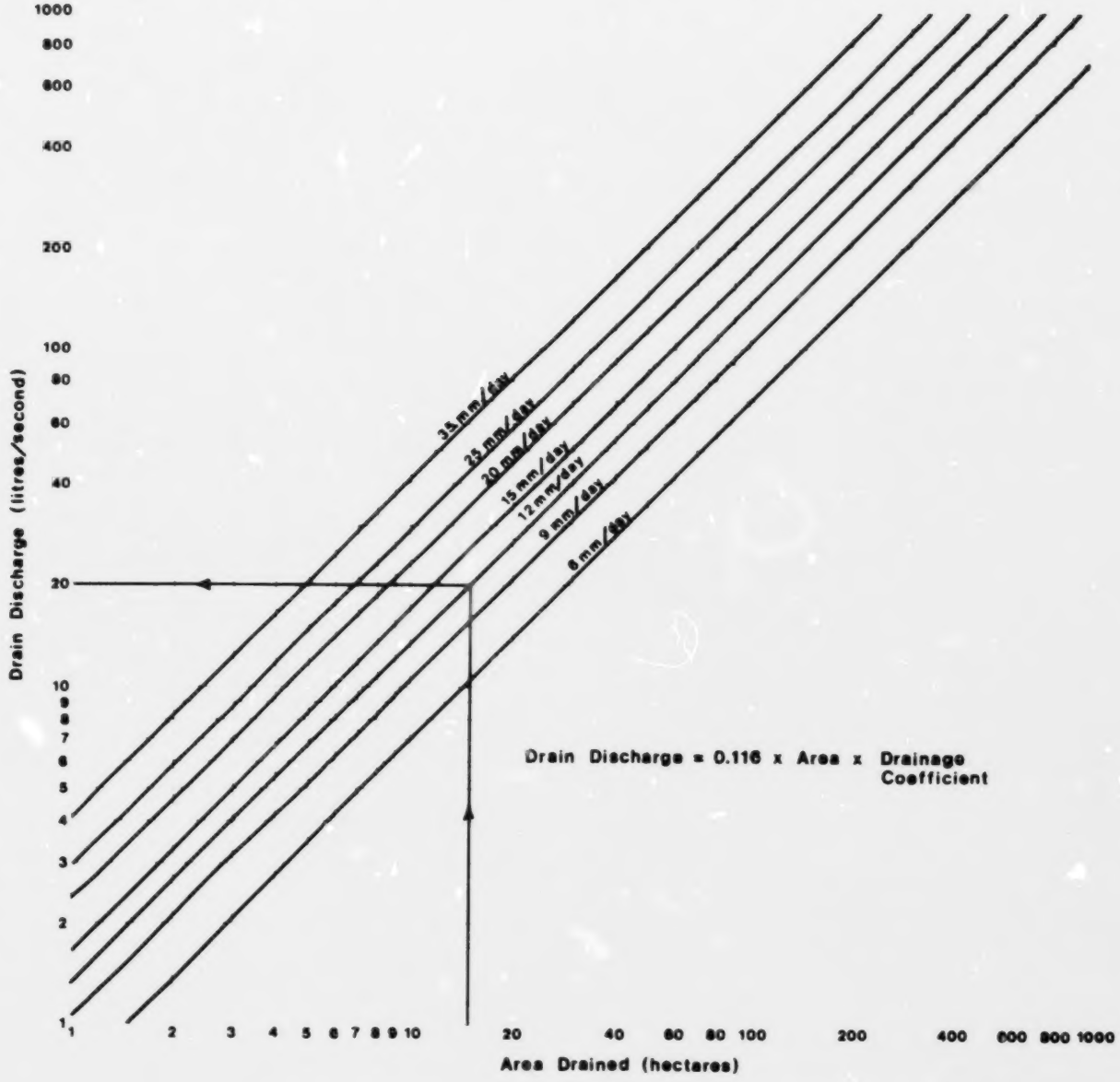

Figure 2. Drain discharge from area drained

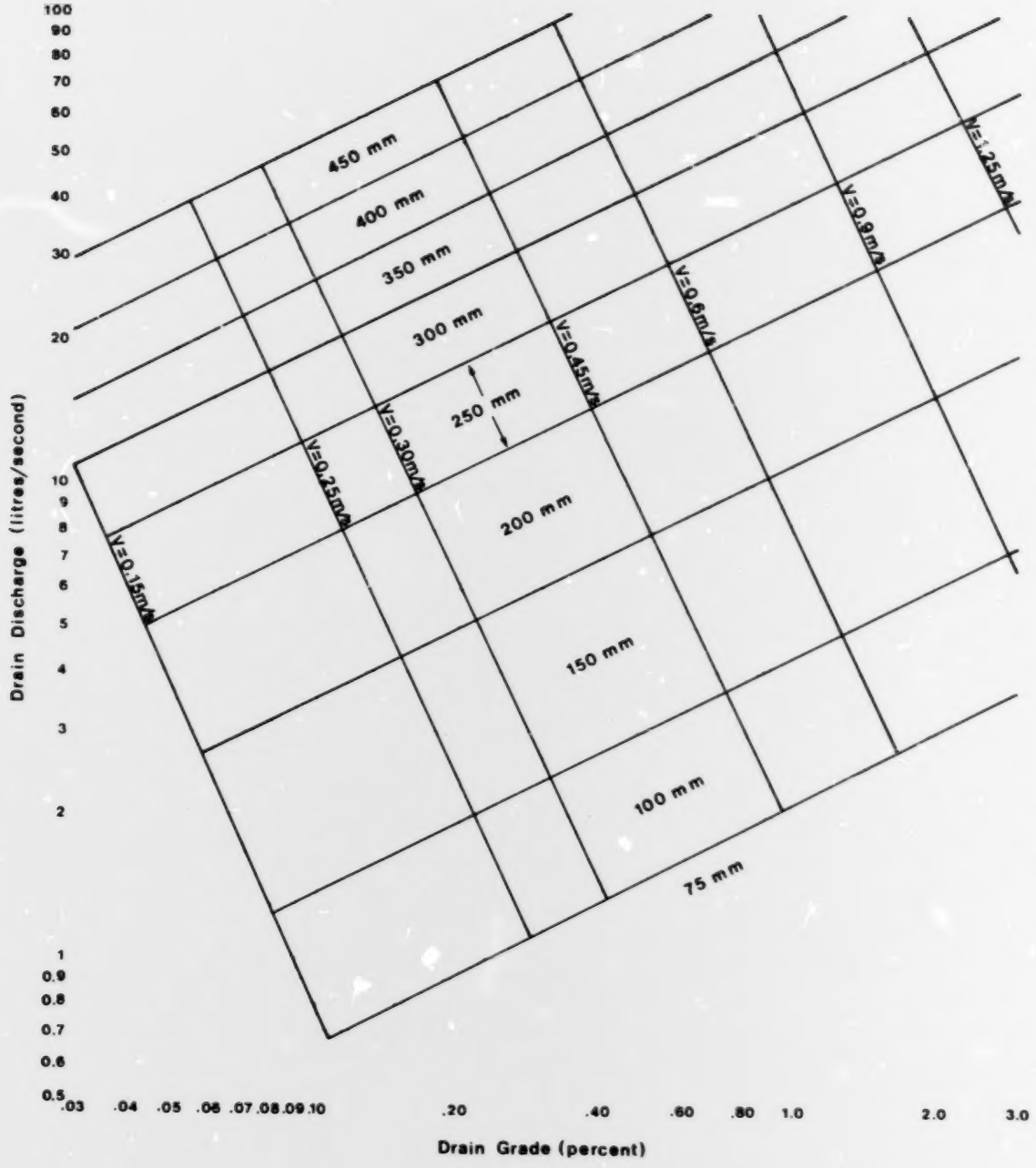

Figure 3. Drain diameter of corrugated plastic drainage tubing

Space between lines is the range of capacity for the size shown.

V = velocity of water, m/s

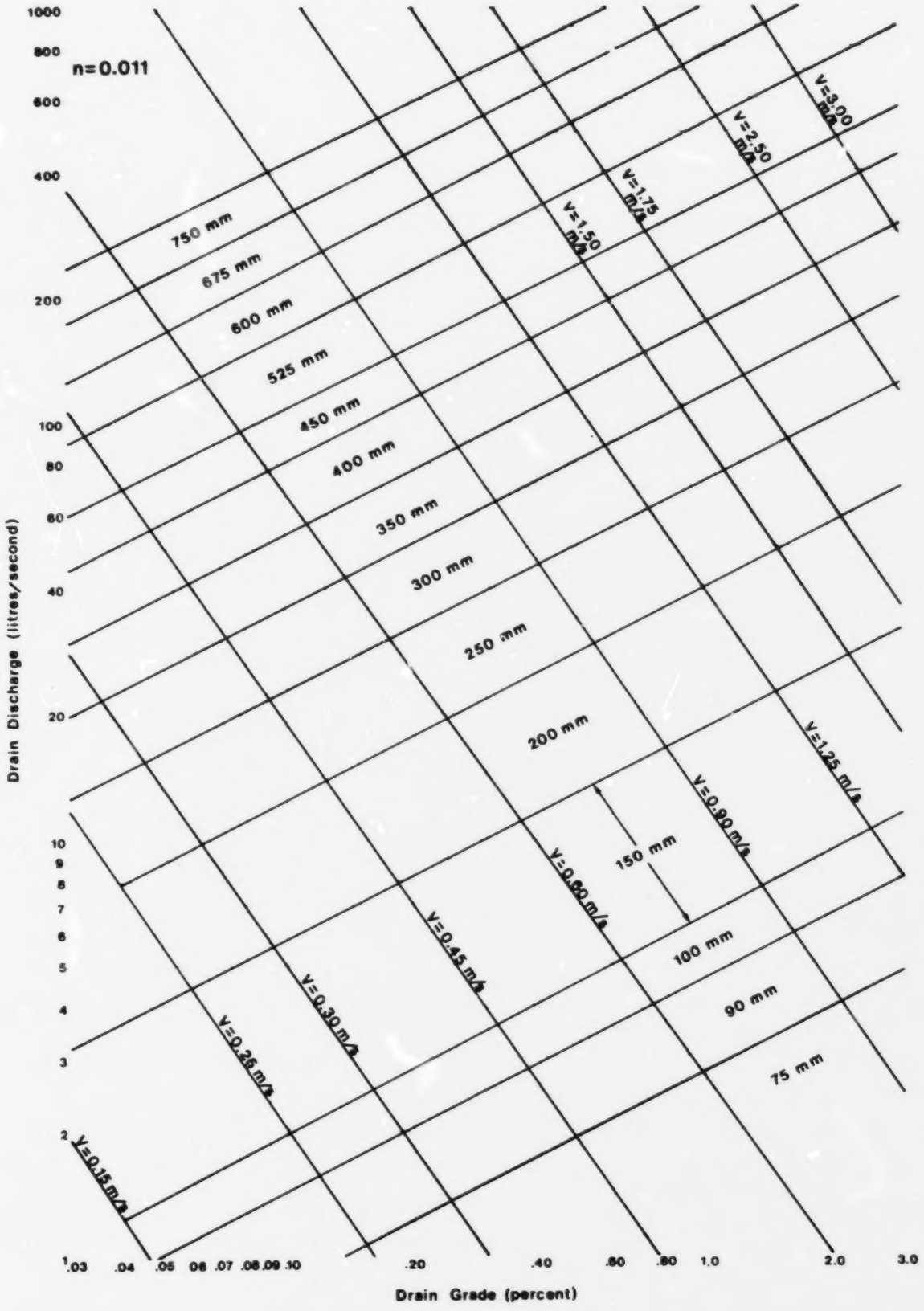

Figure 4. Drain diameter of concrete and clay tile

2.11.6 The required diameter D (mm) of a drain pipe can also be obtained using a hand calculator, from the equation:

$$D = 122.6\,(D_C An)^{0.375} s^{-0.1875}$$

where D_C is the drainage coefficient (mm), A is the area (ha), n is the Manning pipe roughness, and s is the grade in %.

.1 Manning pipe roughness factor used to calculate Figure 4 is 0.011. Figure 3 is constructed using a variable Manning pipe roughness. These were: 75 mm — 0.015; 100 — 0.016; 150 — 0.017; 200 — 0.018; 250 — 0.019; 300 — 0.020; 350 — 0.021; 400 — 0.022.

2.11.7 The flow rate of large diameter corrugated plastic tubing can be estimated from the equation:

$$Q = 7.56\,D^{2.5} s^{0.5} \left(\frac{R}{\lambda}\right)^{0.38}$$

where Q is the pipe discharge, m^3/s; D is the internal pipe diameter, m; s is the unit gradient, m/m; and λ is the spacing between corrugations m; R is the internal pipe radius, m.

2.12 Seepage Interception

2.12.1 An interceptor drain should be located so that it crosses the slope and intercepts seepage water before water reaches the ground surface. This can be done by locating the drain up the slope from the seepage area and placing it perpendicular to the flow path, approximately at the impervious layer along which the groundwater flows.

2.12.2 When the source of seepage water is vertically from below, the drains should be placed deeper and closer in the wet area. A cross-drain between adjacent lateral drains in the wet area, with gravel backfill, should also be considered.

2.12.3 The size and capacity of single random interceptor drains can be determined from Figures 3 or 4 when designed for the inflow rates shown in Table IV.

TABLE IV
INFLOW RATE TO INTERCEPTOR DRAINS

Soil Texture	Inflow Rate per 100 m of Drain (L/s)[1,2]
Coarse sand and gravel	1.0 - 3.5
Sandy loam	0.5 - 1.5
Silt loam	0.2 - 0.75
Clay and clay loam	0.02 - 0.50

1. *Discharge of flowing springs, or direct entry of surface water through a surface inlet or blind inlet, must be added to the above. Such flows should be measured or estimated.*

2. *Inflow rates for interceptor lines on sloping land should be increased by 10% for land slopes 2 to 5%, by 20% for slopes 5 to 12%, and by 30% for slopes over 12%.*

To use Table IV determine the total inflow for the interceptor drain from the data above and enter the left side of Figure 3 or 4 with this value. Move horizontally to the right until you intersect the grade of the drain. This point locates the diameter of pipe required.

For example, assume the inflow rate from a sandy loam soil is 1.50 L/s. The design discharge from a 500 m drain across a slope of 7% is $1.50 \times (500 \div 100) = 7.5$ L/s for a land slope less than 2%. This value must be increased by 20% for a 7% land slope, i.e. $7.5 \times 0.20 = 1.5$ L/s. The design flow is therefore $7.5 + 1.5 = 9.0$ L/s. If the grade on the drain was 0.5%, then Figure 3 shows the required diameter of corrugated plastic drainage tubing is 200 mm.

2.13 Minimum Diameter of Lateral Drains

2.13.1 The minimum recommended diameter of pipe for lateral drains is 100 mm. Seventy five diameter pipe may be used in locations where the grade will produce a clear water velocity greater than 1.15 m/s. (See Table VI.)

2.14 Length of Lateral Drains

2.14.1 The maximum length of lateral drain is restricted by the area which will cause the drain to run full, and may be calculated as follows. Enter Figure 3 or 4 with the grade of the drain and determine the discharge, enter Figure 2 and determine the drained area, in hectares (ha), for a pre-selected drainage coefficient. Calculate the maximum length of drain, L, (m) from the equation.

$$L = \frac{ha \times 10{,}000}{S}$$

when S is the lateral drain spacing (m).

2.14.2 The minimum length of drain is usually greater than two times the drain spacing.

2.15 Depth of Drains

2.15.1 Drain depth is affected by the design watertable depth for crops, available outlet depth, stoniness of the soil profile and soil properties. Examine the soil profile before selecting the depth of drains (See Figure A-1).

2.15.2 The depth is the distance from the ground surface to the bottom of the trench.

2.15.3 Drain cover is the distance from the ground surface to the top of the drain pipe.

2.15.4 It is recommended that the depth of drains be in the range shown in Table II or III.

2.15.5 The minimum cover for main drains is 600 mm for pipe diameters up to and including 150 mm. Minimum cover should be 750 mm for pipe diameters 200 mm or greater.

2.15.6 The minimum cover for lateral drains is 500 mm, and may be used under the following conditions, provided the lateral spacing is adjusted and heavy equipment will not traverse the drain lines, otherwise use 600 mm.

.1 for slowly permeable soils
.2 where rock, stones, sand or dense soil prohibit greater depth

.3 in depressional or impounded areas
.4 where outlet depth is limited
.5 where drains are to be used for subirrigation

2.15.7 Where it is impossible to obtain this minimum cover, continuous rigid perforated pipe should be used or the area should be filled with earth until sufficient cover is provided.

2.15.8 Pipe that meets the standards set out in Section 6 will withstand earth pressure in trenches up to 2 m deep and 500 mm wide. Trenches constructed by conventional farm trenching machines in Ontario will not normally exceed these maximum cover limits. If very deep and wide trenches are to be used, seek advice from a drainage engineer familiar with the design of deep drains.

2.15.9 Drains should be installed so the dead load of the soil and impact and live loads of machinery does not exceed the minimum strength of the drain pipe as specified in Section 6. The percent of live and impact loads transmitted to the drain pipe are shown in Table V for a vertical wall trench.

TABLE V
PERCENT OF APPLIED SURFACE LOAD ON BURIED PIPE

Depth to top of pipe (mm)	Trench Width at Top of Pipe (mm)			
	300	600	900	1200
300	17	26	28	29
600	8	14	18	21
900	4	8	11	14
1200	3	5	7	9
1500	2	3	5	6

2.15.10 Lateral drains should not be deeper than 750 mm in medium to coarse sandy soils as excessive drainage may cause drought of the surface soil.

2.15.11 The cost of installation often increases with depth of drain and must be considered in the design.

2.16 Grade

2.16.1 Subsurface lateral drains are normally placed on uniform grades and as close to uniform depth as topography permits. In design, the grade of the invert of the drain is assumed to be parallel to the hydraulic grade line. It is also assumed that the hydraulic grade line remains within the drain; that is, the drain does not run full under pressure.

2.16.2 Grade should be as great as possible on flat land but cover must not be sacrificed to obtain it. (See 2.15.6)

2.16.3 Minimum grades are shown in Table VI. The selected grade should, if possible, be sufficient to result in a non-silting velocity of 0.45 m/s. Where this cannot be achieved it may be necessary to include silt basins in the system design. Where sedimentation is not a hazard the recommended minimum grade is based on a velocity of 0.15 m/s. Where minimum grade is not available, ensure that a uniform grade is used. Interpolation between ranges is permissible.

TABLE VI
RECOMMENDED MINIMUM GRADE (%)

Drain Diameter	Clear Drains* Not subject to sediment		Drains Subject to sediment	
(mm)	Smooth** Pipe	Corrugated Pipe	Smooth** Pipe	Corrugated Pipe
(1)	(2)		(3)	
75	.08	.10	.48	1.0
100	.05	.08	.32	0.7
150	.025	.06	.18	0.5
200	.02	.04	.12	0.4
250	.018	.035	.09	0.3
300	.012	.03	.07	.025

* *The grades in column 2 provide a minimum velocity of 0.15 m/s at full flow and in column 3 provide 0.45 m/s at full flow.*
** *Well aligned clay, concrete and other smooth wall pipe.*

2.16.4 Maximum grade of main drains should not produce velocities exceeding the following:

Soil texture	Velocity m/s
Sand — sandy loam	1.0
Silt — silty loam	1.5
Silty clay loam	1.75
Clay & clay loam	2.0
Coarse sand & gravel	2.5

When these velocities are exceeded protective measures are required to prevent soil failure. Velocity is determined from Figure 3 or 4. Interpolate between ranges for other soils.

2.16.5 Recommended maximum grade of lateral drains should not exceed 2%.

2.16.6 Design of Main Drains on Steep Slopes

.1 Drain pipe uniform in size and shape, closely laid, well aligned and with smooth ends, or in a continuous length, should be used.
.2 A steep slope is defined as a slope where a partially filled drain pipe will have a Froude Number ($F = V/(gD)^{1/2}$ greater than 1. That is, the minimum velocity, V, in m/s is $3.13\ D^{1/2}$, where D is the pipe diameter in metres.
.3 Short lengths of main drain on steep slopes should be designed to flow half-full.
.4 When the drain is designed to flow half-full, and when the grade is from 1 to 4% in sandy soil, from 2 to 6% in silt or loam soil, or from 6 to 15% in clay soil, draintile joints should be wrapped and protected. The soil should be tamped firmly around the drain, or continuous nonperforated pipe should be used.
.5 When grades exceed those specified above, continuous rigid or nonperforated flexible pipe should be used.
.6 When the drain is designed to flow full, and when the grade is over 1% in sandy soil, over 2% in silt or loam soil, and over 6% in clay soil, continuous rigid or nonperforated pipe should be used.

.7 A relief well (para 3.4) should be installed at the bottom of steep sections unless the drain discharges directly into an open ditch.
.8 A breather (para 3.4) should be installed at the top of steep sections to prevent negative pressure in the drain.

2.17 Principles of Drain Layout

2.17.1 The objective of a subsurface drainage system is to provide uniform drying of the field surface so field operations can occur as required and crops are not harmed by excess water on the surface or in the root zone.

2.17.2 Primary Considerations

.1 Walk over the area to determine possible outlets, low problem areas, high ridges, history of cropping practices.
.2 Evaluate the soil profile to ensure its drainability and determine construction problems such as very fine sand, gravel, large stones, shallow bedrock, iron ochre, or high watertable.
.3 Draw a topographic map of the area at a scale sufficiently large for planning, showing obstructions such as fences, trees, buildings, utilities and outlets.
.4 Based on the available outlet elevation, the elevations of key problem areas, and Sec. 2.15 of this Guide, select the average depth of lateral drains.
.5 Allow for possible sedimentation of the outlet when selecting the outfall elevation.
.6 Check the legal status of the outlet.
.7 Check for Utility easements and for permits required.

2.17.3 Secondary Considerations

.1 Take full advantage of the surface slopes and try to maintain as uniform a depth of drain as the land surface permits.
.2 For economy, design the system with long lateral drains and short main drains. Care must be taken that long lateral drains are not too deep.
.3 When feasible, layout lateral drains at right angles to the direction of surface water flow.
.4 When feasible, layout lateral drains at right angles to the normal farming pattern.
.5 On flat land (0.1% or less) plan lateral drains in the direction of greatest surface slope.
.6 Follow the general direction of natural waterway with mains and submain drains. When possible drains should be offset from the lowest elevation to avoid reduced cover and erosion damage.
.7 Watertable levels should be controlled deep enough to provide for optimum root development of the deepest rooting crop to be grown.
.8 The diameter of the main drain, and long lateral drains, is obtained from Sec. 2.11. Drain capacity varies as $D^{2.67}$, so small changes in pipe diameter causes large changes in capacity.
.9 Existing subsurface drains must be connected to the new system through a direct or indirect connection.
.10 Stub drain lines, at closer spacing, may be needed in some fields to successfully drain small areas of wetter land, particularly springs and seepage areas.
.11 Use a cut-off at the high end of fields so surface water will not run onto the field.
.12 Use as few outfalls as possible.
.13 Avoid excessive cuts.
.14 Avoid very wet soil conditions.
.15 Outlet in the most suitable location.

3.0 DRAINAGE SYSTEM STRUCTURES

3.1 General

3.1.1. A drain system structure is an auxiliary structure to a subsurface drainage system. Typical structures are pipe drops, headwalls, junction boxes, surface water inlets, manholes, catch basins, sand traps, relief wells, outfall structures, and special design structures.

3.1.2. The principal purposes of drain system structures are to protect the outfall of drains, control grade and velocity, regulate flow, connect drains, collect sediment and debris, provide access for inspection, prevent erosion, regulate water table levels, and relieve hydrostatic pressures.

3.1.3. The number, type, and size of structures needed are generally determined during surveys and the design of the drain line. Soil borings should indicate any need for special foundation design.

3.1.4 Structures installed in drain lines should not restrict the flow in the system. Structures should have a capacity not less than that of the drain, or of those feeding into or through them. Where the drain system will carry the entire surface flow, the surface water inlets should have a capacity determined by hydrologic procedures for the drainage area served by the inlet. Open channels and waterways should be designed in conjunction with drain systems to carry a portion of the surface runoff wherever feasible.

The drain system should be protected against high velocities and turbulence created near outfalls, surface inlets, or similar structures.

3.2 Surface Inlets

3.2.1 Surface water inlet structures should be equipped with screens, trash racks, or gratings to exclude floating debris and stop rodent entry.

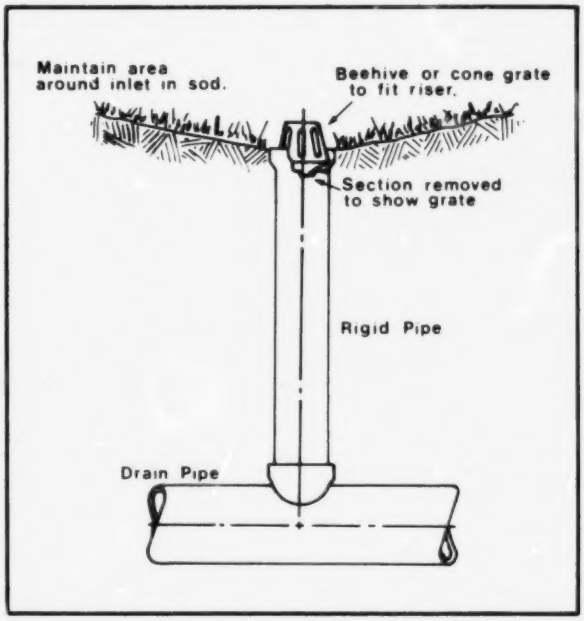

Figure 5. Surface water inlet

3.2.2 Open surface inlets (catch basins) (Figure 5) present a maintenance problem and should only be used where shallow surface drains are not practical. They may be necessary for rapid removal of surface water concentrated in depressional areas where specialized crops are grown, or where surface water from higher areas is to be routed underground to prevent it from flowing across a flat cultivated area. Surface inlets should be offset from the drain line. A built-in sediment trap should be provided. Use a 1-m length of corrugated steel pipe (C.S.P.) on the inlet and outlet to the catch basin to prevent frost damage to clay drain tile.

Example application of surface inlets are at:

- **.1** A fence line or other boundary where the subsurface system picks up surface water from an adjoining area.
- **.2** A ditch where water from the ditch enters a subsurface system.
  - **.1** The crest of the inlet should be the same elevation as the ditch bottom.
- **.3** A depressional area where specialized crops are grown which require very rapid removal of surface water.
- **.4** A depressional area where soil with low permeability is present and a blind inlet will not have sufficient capacity (See 3.2.4).
- **.5** An erosion control structure where surface waters are diverted to a subsurface system to prevent erosion from the concentrated overland flow: A floodwater storage system is often incorporated into the design.

3.2.3 Ditch inlets (Figure 6) are structures which permit surface water in a ditch to enter a subsurface drainage system, but does not permit entry of rodents.

- **.1** The grade of the ditch has a negligible effect on inlet capacity.
- **.2** The crest of the inlet should be the same elevation as the ditch bottom.
- **.3** The grate should have longitudinal bars spaced 125 mm apart to prevent clogging of debris. Bars spaced 60 mm apart collect six times as much debris and adversely affect the inlet flow rate. Cross-bars also collect debris.
- **.4** The grate should be installed at an approach slope of 1:1.
- **.5** A trash guard should be used upstream from the inlet.
- **.6** The required horizontal width of the unobstructed inlet can be estimated from Figure 7.

For example, assume a ditch has a design flow of 0.15 m^3/s and the design head on the inlet is 0.20 m. Enter Figure 7 at 0.20 m depth of flow and determine the flow rate per unit width of inlet is 0.22 $m^3/s/m$. The design width of the inlet is $0.15 \div 0.22 = 680$ mm. The width may be increased by 50% to allow for obstruction by corn leaves, etc.

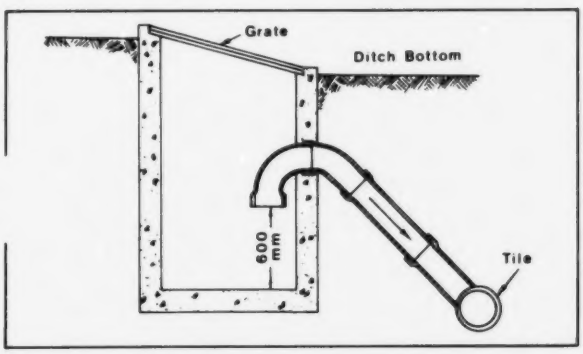

Figure 6. Ditch inlet

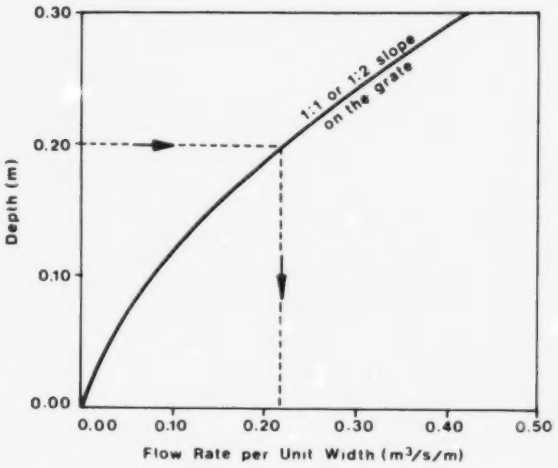

Figure 7. Ditch inlet design chart

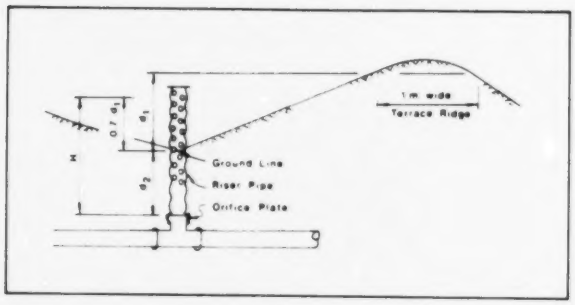

Figure 8. Riser inlet design head on orifice plate

3.2.4. Riser Inlets may be used for small flows especially if potential trash problems exist. Figure 8 shows an installation. To prevent trash from plugging the inlet, the capacity of the holes should not be the limiting factor. The capacity should be controlled by installing an orifice plate at the bottom of the inlet.

.1 The design head on the orifice plate may be calculated from

$$H = 0.7d_1 + d_2$$

where d_1 is the depth of the terrace channel below the designated elevation at the terrace ridge where it is 1 m wide, d_2 is the depth to the orifice plate below the ground level of the terrace channel.

.2 The discharge, Q, of a riser outlet may be calculated from

$$Q = 2.66\ A\ H^{1/2}$$

where Q = m^3/s, H (head on orifice plate) = m, A = m^2) (area of orifice).

3.2.5 Blind Inlets (Figure 9) are recommended for depressional areas in fine-textured soils where shallow surface drains are not practical and/or where surface ponding occurs. A 500 mm wide trench 3000 mm long, filled to the top of the trench with 15-30 mm porous stone, serves as an excellent inlet.

.1 A geotextile placed horizontally at 300 mm deep will add to the life of the inlet. Only the upper layer of gravel will require replacement.

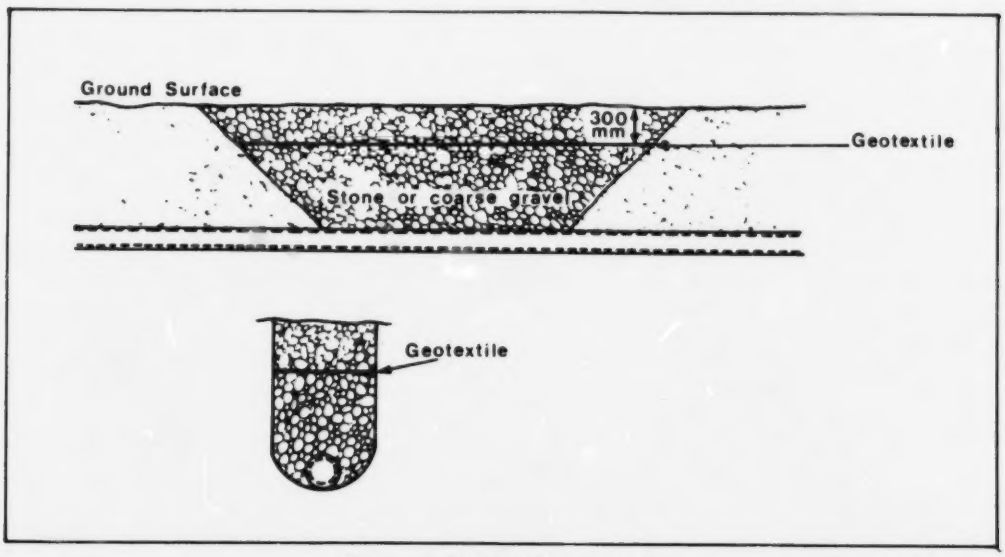

Figure 9. Blind inlet to drain line

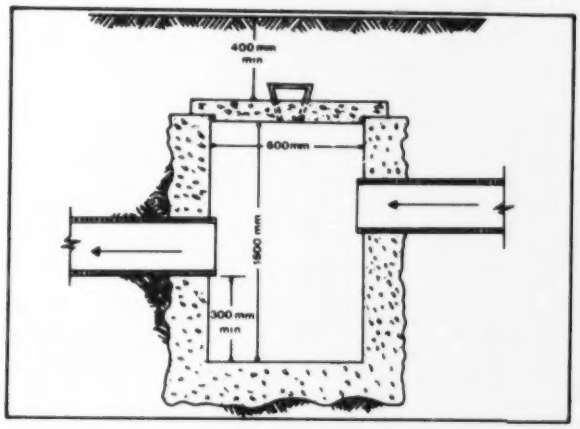

Figure 10. Silt basin

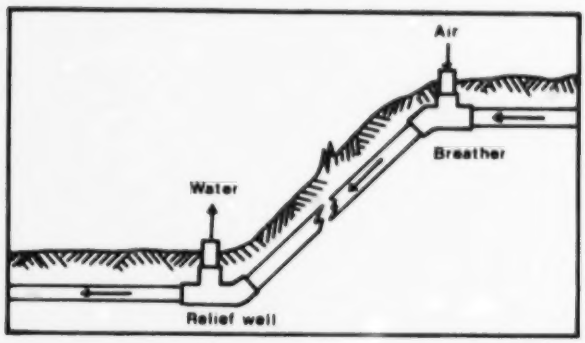

Figure 11. Breather and relief well

3.3 Silt Basins and Junction Boxes

3.3.1 These types of structures (Figure 10) are used as settling chambers to separate sediment from water and for access inspection points in the drainage system to be used:

(a) down grade from where a drain passes through a problem sandy area; or

(b) where two or more large drains join together at different elevations.

If possible, they should be located at permanent fences or in non-cultivated areas. If installed in cultivated areas, the top of the structure should be a minium of 400 mm below the ground surface and its location "referenced in".

3.3.2 The size of junction boxes, catch basins, and sand traps should be based on accessibility for maintenance. Circular structures should have a minimum diameter of 750 mm. For square or rectangular structures, the minimum dimension should be 600 mm.

3.4 Breathers and Relief Wells

3.4.1 It may help to install a breather (Figure 11) or vent at the upper end of a very steep section of main drain and a relief well at the base of the slope. These accessories improve the flow in the drain, reduce the hazard of drain failure, and often the need for changing pipe sizes. They should be located in fencelines. (See 2.16.6)

3.4.2 Breathers may be useful on very long lateral drains in waterlogged soil where the gradient is less than 0.05%.

3.4.3 A relief well may relieve the positive pressure in a drain in which the pressure might otherwise cause a drain failure and/or a soil blowout.

3.4.4 Relief wells should be located at points where the drain may become pressurized for a short period of time, such as where the grade changes from steep to flat. If possible, locate them at fence or property lines.

3.4.5 The capacity of the relief well system should be based on the estimated flow from the drain and other site conditions.

3.4.6 The diameter of vertical relief wells should not be less than 150 mm.

3.5 Outfall Structures

3.5.1 Drains that discharge into a ditch or watercourse should be protected against erosion and undermining. A length of continuous rigid, non-perforated pipe should be used as an end pipe. Outfalls for plastic tubing drainage systems also must be protected against weather, fire and animal damage, as well as crushing.

3.5.2 Flush mounted outfalls may be used (Figure 12) and provide a better outfall design where sufficient erosion control protection has been incorporated.

3.5.3 The inside diameter of the end pipe should not exceed the outside diameter of the drain pipe by more than 50 mm for a sleeve joint.

3.5.4 A hinged grate should be attached to the end pipe at the time of installation. Grate openings should not exceed 25 mm. The design of the grate should permit removal of debris.

3.5.5 The outfall should have a miminum freeboard of 300 mm above the normal ditch water level. Future sedimentation in the outlet ditch should be considered.

3.5.6 Drains may be designed for submerged conditions where circumstances warrant and where special precautions have been included in the design.

3.5.7 The minimum dimensions of end pipe are shown in Table VII. The pipe should be embedded in the bank to provide needed support. The end pipe should be installed as soon as the drain is constructed. An example is shown in Figure 13.

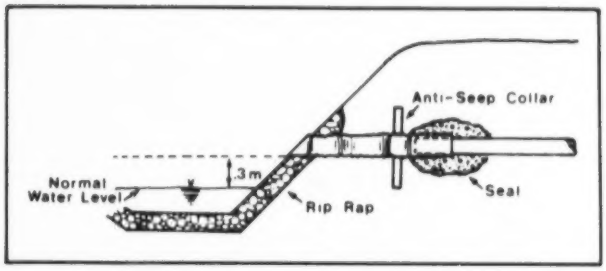

Figure 12. Flush mounted drain outfall

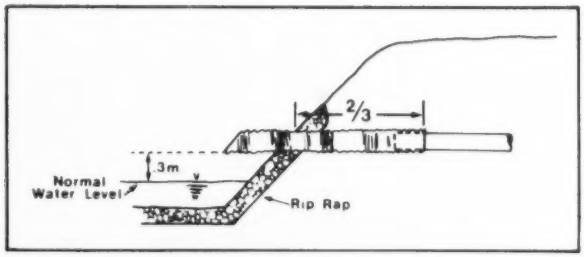

Figure 13. Cantilever style drain outfall

TABLE VII
DIMENSIONS OF END PIPE

Nominal Drainpipe Diameter (mm)	End Pipe Dimension		
	Minimum Diameter (mm)	Minimum Length (mm)	Maximum Cantilever (mm)
100	150	3600	400
150	200	3600	600
200	250	3600	600
250	300	3600	600
300	400	4200	800
350	400	4900	800
400	500	5500	800
450	600	6000	1000

4.0 UTILITIES AND ROAD CROSSINGS

4.1.1 Defininition

4.1.1 The word "Utility" as used in Section 4.0 is meant to include the works of a Public Utility as defined in the Drainage Act and the works of a road authority. The Utility should ensure that the quality of drainage within the right-of-way after construction is equivalent to or better than, the drainage in the work area and adjoining lands prior to construction.

4.1.2 On farm land, construction work, such as pipe and cable-laying, disrupts installed drainage systems. Systems must be inspected carefully to ensure proper repair after construction is complete. The location of Utilities and roads may also affect the design of new drainage systems.

4.1.3 Prior to installation of utility works the Utility should enquire of the owners whether new or additional drainage installations are to be made across the proposed right-of-way so that suitable arrangements can be made.

4.1.4 Prior to drainage installations being made near existing Utility works, the property owner should advise Utilities so that they may locate and mark the works and right-of-way easement to prevent damage. It is extremely important that the property owners and/or contractor contact the respective Utilities so that adequate and proper arrangements can be made for drain/Utility crossings without delay to the work.

4.2 Recommendations

4.2.1 The recommendations listed below should be followed to ensure that there is full coordination between the landowner, the contractor and the Utility, and that a drainage system will function properly after being traversed by a Utility.

4.2.2 Open Ditches A completed Utility work should not interfere with the flow of water in a drainage ditch.

4.2.3 At the point where a Utility work crosses a ditch, the ditch banks should be protected from slides and erosion.

4.2.4 All debris and rubbish should be removed from the ditch before leaving the site.

4.3 Existing Subsurface Drains

4.3.1 The Utility should be responsible for the repair of all subsurface drains damaged by their construction work, on or off the right-of-way.

4.3.2 Drains damaged, cut, or removed should be temporarily repaired immediately in such a manner that the drainage system will function properly or the ends must be covered to prevent the entry of soil.

4.3.3 Drain pipe damaged, broken, collapsed, or where the grade has been altered, should be removed to a distance 1 m beyond the affected area, and be replaced by new pipe of the same size and on the proper grade.

4.3.4 Where a work area extends over land which contains lateral subsurface drains, the Utility should ensure that work on the surface does not adversely affect the subsurface drains through breakage or collapse of pipe. The above may be checked by:

.1 A visual inspection up the pipe using a strong light where the distance does not exceed 10 m, or
.2 Inserting a probe of 75 mm o.d. through the pipe for the width of the work area to ensure no blockage through tubing collapse or tile breakage.

4.3.5 Where a Utility work undercrosses a drain line, there should be a minimun clearance of 100 mm between the invert of the drain line and the top of the Utility work. If it overcrosses a drain line, a minimum clearance of 100 mm is required between the top of the drain pipe and the bottom of the Utility work.

4.3.6 Where a drainage system is undercrossed, the fill below the drains must be tamped and compacted to the same density as the surrounding soil. The material used must be well-pulverized soil, free from stone, debris, or frozen lumps. The trench bottom must be shaped and planed to the original grade, and a satisfactory support placed under the drain. The drain pipe should be blinded with 100 mm of stone-free soil and the trench backfilled, leaving a minimum crown of 200 mm.

4.3.7 Drain crossings (that portion of the disturbed subsurface drain across the Utility work excavation) wider than 3 m should be a metal pipe or other high-strength, continuous, rigid pipe (joints to be clamped with regular manufactured connecting bands) or a pipe of larger diameter than the drain pipe and so installed and tamped that it will not be crowded out of line by vibration or frost. The joint at each end should be sealed with concrete. For crossings less than 3 m, drain pipe must be laid on a satisfactory support. In unstable soils additional support is required.

4.3.8 Where the Utility work excavation has cut a series of lateral drain lines, it is recommended that a new main drain be constructed, parallel to the upstream side of the Utility work, or right-of-way easement with a minimum number of crossings of the Utility. A silt basin should be constructed at the downstream side of the right-of-way for each drain crossing. The upper end of severed drains should be closed tightly with an end plug.

4.3.9 All drain lines must be carefully inspected prior to backfilling to ensure that the pipes are true to grade, correctly aligned and properly installed. The allowable variation from grade must be not more than that specified in 7.6.5

4.3.10 The ground surface should be graded to eliminate depressions in which water might collect.

4.3.11 New drainage systems should be designed where possible, to reduce the number of crossings by the use of submains parallel to the Utility facility or right-of-way.

4.3.12 Where an easement is greater than 10 m in width a lateral drain should be installed in the easement to provide uniform drainage.

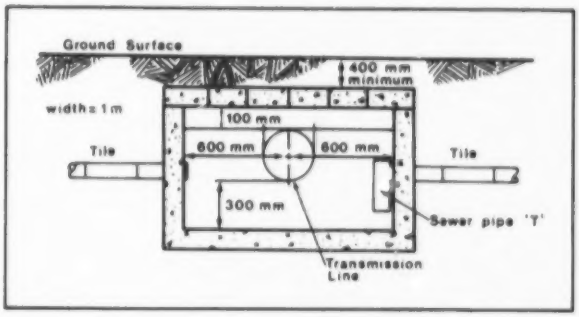

Figure 14. Juncton box utility crossing

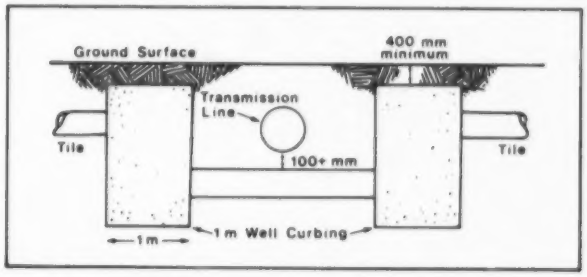

Figure 15. Inverted siphon utility crossing

4.3.13 Where drains will not go over or under a work without a deviation from grade, one of the following methods may be used:
.1 If a service can be disrupted, lower the work.
.2 Construct a junction box around the work (Figure 14).
.3 Construct an inverted siphon (Figure 15)
Ref.Jnl. Hydraulics, ASCE, 1972 No. 1, p. 45.

4.4 "Call Before You Dig"

4.4.1 NOTE: Utility approval is required prior to installation.

5.0 DRAIN MANAGEMENT PROBLEMS

5.1 Trees

5.1.1 Drains that are within 15 m of trees and which carry water for prolonged periods during the growing season may become plugged with tree roots. If possible, all water-loving trees, such as willow, soft maple, elm, and poplar, should be removed for a distance of 30 m from the drain; other trees should have a clearance of 15 m. If a tree cannot be removed or the drain rerouted, use continuous nonperforated pipe for a distance of 15 m on either side of the tree.

Fruit trees are not included in these recommendations. However, a header drain should be located at the higher end of an orchard to intercept seepage water that might cause prolonged flow in lateral drains.

5.2 Quicksand

5.2.1 Quicksand is a condition, not a particular type of soil material. The upward pressure of water and the soil material may adversely affect the grade of the drain and the life of the system.

5.3 Iron Ochre

5.3.1 Iron ochre affects about 2 per cent of drainage systems in Ontario. This natural condition is usually found where new land which is sandy in nature and has a high organic matter content, is cleared and drained. Iron ochre is usually recognized by a brilliant red accretion at drain outfalls. Ochre will seal the inlets to drains very quickly.

5.4 Animal Waste

5.4.1 Organic waste, when spread on the field in high concentration, may create organic growths in field drains which plug the systems very quickly. Similarly, barnyard effluent and milk house water often plug drains due to the enriched drainage water. Do not permit polluted water to enter a drain.

5.5 Crop Roots

5.5.1 Crop roots do not usually penetrate into drains. When drains carry water during dry periods, crops such as alfalfa, brome grass, rye grass, canola, or corn may create some problems with roots. These roots often will wash out of the drain when the plant dies.
Horsetail (Equisetum) has a deep root system and frequently will plug drains.

5.6. Problems

5.6.1 The above problems are discussed in more detail in OMAF Factsheet, *Drain Problems*, Agdex 752.

6.0 MATERIALS AND STANDARDS

6.1 General

6.1.1 Materials used in subsurface drainage systems should meet the requirements of the relevant Standard.

6.1.2 The owner should determine the presence of deleterious chemicals which may be present in the soil in which the drainage system is to be installed. Concrete pipe should not be installed in soils containing sulphate unless they are manufactured using sulphate resistant cement. Soils containing traces of iron should be examined to ensure the proposed drainage system will be effective in such soils. (See OMAF Factsheet, *Iron Ochre*, Agdex 752).

6.1.3 Clay and concrete drain pipe should be straight and approximately circular in cross-section. Ends should be square and the inside surface smooth. Pipe should be free from cracks, broken pieces, and checks which may decrease strength or admit soil into the drain. Where drain pipe may be crushed owing to loads applied by machinery or other traffic or where frost is a problem, use sewer pipe or corrugated steel pipe.

6.2 Clay Drain Tile

6.2.1 Major manufacturers adopted for voluntary use in Ontario a recommendation "that Standard Clay Drain Tile shall meet all American Society for Testing and Materials specifications as set out in designation C4 (Clay Drain Tile) and Designation C498 (Perforated Clay Drain Tile) with the exception of the absorption factor and the freeze and the thaw test. Extra-Quality Drain Tile, and Heavy-Duty Tile, shall meet all specifications as set out in Designation C4 and Designation C498".

A summary of this Standard Specification is presented in Table VIII.

6.3 Concrete Drain Tile

6.3.1 Major manufacturers adopted for voluntary use in Ontario a recommendation "that Concrete Drain Pipe shall meet the specifications as set out in American Society for Testing Materials Designation C412 (Drain Tile)".

6.3.2 A Summary of this Standard Specification is presented in Table IX.

6.4 Corrugated Plastic Drainage Tubing

6.4.1 Major manufacturers adopted for voluntary use in Ontario the Canadian General Standards Board standard 41-GP-29 Ma, Corrugated Plastic Drainage Tubing, for use in subsurface land drainage and in residential construction applications limited to foundation and underfloor drainage. The standard applies to diameters of 75 mm — 300 mm.

6.4.2 A summary of the Standard follows:

- **.1** Material shall be resistant to the chemicals present in soils and ground water and shall provide protection against degradation by ultra-violet light.
- **.2** Tubing must be uniform in colour and density and free from visible defects.
- **.3** Tubing may be nonperforated (Type 1), or perforated (Type 2). In Type 2 tubing the water opening area shall not be less than 16 cm^2/m of tubing. Water openings shall be located in the bottom of exterior corrugation valleys.
- **.4** Individual inlet openings are to be uniformly spaced in not less than 3 rows along the length of the tubing. The greatest width of inlet opening shall be between 1 and 2 mm.
- **.5** The tubing shall have a stiffness of not less than 170kN/m^2 at 5% defection and 130 kN/m^2 at 10% defection, when tested on a parallel plate.
- **.6** There should be no evidence of a crack or split following crush, impact, bending and straightening tests.

TABLE VIII

ASTM PHYSICAL TEST REQUIREMENTS FOR CLAY DRAIN TILE

STANDARD DRAIN TILE			EXTRA-QUALITY TILE**				HEAVY-DUTY TILE**			
Internal Diameter (mm)	Minimum Crushing Strength* (kN/m)		Minimum Crushing Strength* (kN/m)		Maximum Water Absorption by 5-Hr Boiling (%)		Minimum Crushing Strength* (kN/m)		Maximum Water Absorption by 5-Hr Boiling (%)	
	Average of Five	*Individual*	*Average of Five*	*Individual*	*Average of Five*	*Individual*	*Average of Five*	*Individual*	*Average of Five*	*Individual*
100	11.7	9.9	16.0	14.4	11	13	20.4	18.4	11	13
125	11.7	9.9	16.0	14.4	11	13	20.4	18.4	11	13
150	11.7	9.9	16.0	14.4	11	13	20.4	18.4	11	13
200	11.7	9.9	16.0	14.4	11	13	21.8	19.7	11	13
250	11.7	9.9	16.0	14.4	11	13	22.6	20.4	11	13
300	11.7	9.9	16.0	14.4	11	13	24.8	22.3	11	13
350	12.3	10.5	16.0	14.4	11	13	27.0	24.2	11	13
375	12.7	10.8	16.7	15.0	11	13	28.9	26.0	11	13
400			17.5	15.7	11	13	30.6	27.6	11	13

* *Three edge bearing for strength tests.*
** *The number of cycles for freezing and thawing shall be as follows: Extra-Quality 48, Heavy-Duty 48. ASTM Designation C4*

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[1]Copies of the full ASTM Standard specifications may be purchased from the American Society for Testing Materials, 1916 Race St., Philadelphia, Pa., 19103.

[2]**Perforations** must be either 6 or 12 mm in diameter. There should be 4 rows of perforations, with at least three perforations in each row.

TABLE IX

ASTM TEST REQUIREMENTS FOR CONCRETE DRAIN TILE

STANDARD DRAIN TILE					EXTRA-QUALITY TILE					SPECIAL QUALITY TILE***		
Nominal Inside Diameter (mm)	Three Edge Bearing Crushing Strength* (kN/lin m)		Absorption Boiled 5 Hr (%)		Nominal Shell Thickness (mm)	Three Edge Bearing Crushing Strength* (kN/lin m)		Absorption Boiled 5 Hr (%)		3-Edge Bearing Crushing Strength** (kN/lin m)	Absorption Boiled 5 Hr (%)	
	Minimum		*Maximum*			*Minimum*		*Maximum*		*Minimum*	*Maximum*	
	Avg	*Indiv*	*Avg*	*Indiv*		*Avg*	*Indiv*	*Avg*	*Indiv*	*Indiv*	*Avg*	*Indiv*
100	11.5	10.0	10	11	13	16.0	14.5	9	10	16.0	8	9
125	11.5	10.0	10	11	14	16.0	14.5	9	10	16.0	8	9
150	11.5	10.0	10	11	16	16.0	14.5	9	10	16.0	8	9
200	11.5	10.0	10	11	19	16.0	14.5	9	10	16.0	8	9
250	11.5	10.0	10	11	22	16.0	14.5	9	10	16.0	8	9
300	11.5	10.0	10	11	25	16.0	14.5	9	10	16.0	8	9
350					29	16.0	14.5	9	10	16.0	8	9
375					32	16.0	14.5	9	10	16.0	8	9
400					35	16.0	14.5	9	10	16.0	8	9
450					38	17.5	16.0	9	10	17.5	8	9
500					41	19.5	17.5	9	10	19.5	8	9
550					44	21.5	19.0	9	10	21.5	8	9
600					50	23.5	21.0	9	10	23.5	8	9

* *Drain tile meeting the above strength requirements is not necessarily safe against cracking in deep and wide trenches.*
** *For loads in excess of the supporting strengths shown in the above table, tile may be supplied using designs involving the ASTM Designation C412 increase of wall thickness or the use of higher strength concrete.*
*** *For sulfate exposure, sulfate-resistant cement should be specified.*

[3]Canadian General Standards Board publications may be purchased from Canadian Government Publishing Centre, Supply and Services Canada, Ottawa, Ontario, K1A 0S9. Telex 053-4296. Phone 819-997-5641.

6.5 Fittings

6.5.1 Fittings are used to facilitate the construction of a subsurface drainage system and improve its effectiveness, maintenance and efficiency.

6.5.2 Fittings include T's, Y's, end plugs, elbows, clay tile to plastic tubing adaptors, adaptors for changes in diameter, coupling for lengths of plastic tubing.

6.5.3 Fittings must be strong and compatible between manufacturer used.

6.5.4 Corrugated plastic tubing couplers must meet tensile forces specified in CGSB 41-GP-29Ma.

6.6 Envelope and Filter Materials

6.6.1 An envelope material is used to restrain the entry of base soil material which surrounds the drain. Experience has shown that soils, such as fine sandy loams and some silts, with a single grain structure in the range of 50 to 250 microns are susceptible to erosion into drains.

6.6.2 The envelope should completely surround the drain pipe to prevent particle movement into the drain.

6.6.3 The envelope material should be suitable for underground use and possess a long life expectancy.

.1 Thin synthetic filter materials deteriorate in sunlight. Check the date on the production "tag" to ensure it has not been stored too long.

6.6.4 The permeability of the material should be as large as design criteria will permit while still retaining soil material.

6.6.5 During construction any envelope material damaged in transit, storage or construction should be repaired or the envelope replaced .

6.6.6 Envelope materials are often subject to immediate plugging when installed in sand and silt soils having a high water table.

6.6.7 Install drains in sand and silt soils only under dry conditions, or when the watertable is at the lowest elevation.

6.7 Geotextiles

6.7.1 Geotextile materials are synthetic products which are useful in land drainage to improve the drainage, or to improve stability of a structure or the soil. They can be used for vertical drainage as a substitute for gravel. The most important use is as a base material between the soil and armour for prevention of bank erosion and to prevent mechanical failure at outfalls.

7.0 CONSTRUCTION

7.1 General

7.1.1 The purpose of this construction Performance Practice is to define the **minimum standard of work** which the Ontario Ministry of Agriculture and Food considers satisfactory for the construction of subsurface drainage systems used to drain agricultural land.

7.1.2 All agricultural tile drainage systems must be installed in accordance with the Agricultural Tile Drainage Installation Act. The Act requires the licensing of tile contractors, their equipment and equipment operators. Landowners installing tile on their own property with their own equipment are exempted.

7.1.3 This Practice is not intended to be a complete specification since conditions vary in different parts of Ontario. Work conditions may dictate that other construction practices equal to or higher than this Practice be used to meet specific performance conditions. Landowners may impose additional requirements.

7.1.4 Workmanship, materials and methods of construction are to conform to suitable standards and practices. Where it is necessary to excavate a pit to observe the standard or workmanship or materials the owner or contractor is to make labor available to carry out this work.

7.1.5 Other sections in this Guide apply directly to the Construction section and should be reviewed before work is done.

7.2 Safety

7.2.1 Contractors shall comply with existing Provincial laws. Attention is drawn to the Occupational Health and Safety Act and Regualtions.

7.2.2 Systems of work must be adopted and equipment used that are, so far as is reasonably practicable, safe and without risks to persons at work and others who may be at risk from the activities of persons at work.

7.2.3 "Call before you dig." Ensure the location and depth of underground utilities are known and marked before construction.

7.2.4 Persons working in a trench must be protected from cave-ins. Excavations must be safe and adequately supported. Persons should not work alone in trenches.

7.2.5 Moving parts of the drainage machine that may create a hazard must be protected by proper guards.

7.2.6 Casual observers should not be permitted close to construction operations.

7.2.7 Livestock should not be allowed in the field where construction is in progress or where trenches are open.

7.2.8 Safety barricades and warning signs should be erected by the contractor where the public has access to drain construction.

7.3 Inspection and Handling of Material

7.3.1 Inspection of material for drains should be made by the contractor before and during installation. All material should be satifactory for the intended use and should meet the requirements as set forth in Section 6. "Materials" as well as any additional requirements placed by the owner.

7.3.2 Material should be protected from hazards. Care should be exercised during handling to avoid damage to the material.

7.3.3 Inspection Before Installation

.1 Upon delivery of material to a site, it should be examined for damage. Damaged or otherwise unsatisfactory material should be returned to the supplier.
.2 Clay, shale, and concrete pipe should not be subjected to flooding and should be stockpiled on boards or other suitable material to eliminate direct ground contact during periods of freezing and thawing.
.3 Coils of plastic pipe should be protected from damage and deformation by stacking the coils on their side, not greater than 4 coils high, on a level site, free of mud and sharp objects.

7.3.4 During Installation

.1 All pipes should receive a final inspection by the contractor. Defective or damaged clay, shale, concrete or other rigid drain pipe should be rejected; defective or damaged sections of plastic pipe should be cut out and the tubing joined in accordance with paragraph 7.12.5.
.2 Where plastic tubing is to be used, ensure that perforated plastic tubing is installed, except as otherwise specified on the plan.

7.4 Working Conditions

7.4.1 Drains should be installed under favorable working conditions. Saturated land surface conditions and very wet soil profiles should be avoided until the watertable is low.

7.5 Control of Direction

7.5.1 Horizontal direction or alignment should be fixed by sighting guide targets.

.1 Lateral drains should be as straight and parallel as the topography will allow and where uniform depth can be maintained.
.2 The tolerance for horizontal alignment of lateral drain lines intended to be parallel is 3% of drain spacing.

7.5.2 Horizontal direction should be changed in such a way as to maintain the specified grade, not impede the flow of water because of excessive roughness, and allow tile joints to be fitted according to soil conditions.

7.5.3 Horizontal direction may be changed by one of the following methods:

.1 Construct the drain on a gradual curve so that the drainage machine can install the pipe in the trench while maintaining grade.
.2 Construct a gradual curve by shaving the inner side of the curve and chipping the drain tile; however, in no case should the radius of curvature be less than 1.5 m.
.3 Use manufactured bends or fittings so that the change in direction is a smooth curve.
.4 Use junction boxes and silt basins.

7.6 Control of Grade

7.6.1 All drains should be installed to a predetermined grade and line. Accurate grade control must be constantly maintained during installation.

7.6.2 The constructed grade should be such that the drain as constructed will provide the capacity required for the drained area.

7.6.3 A variation in grade can be tolerated where the actual capacity of the drain exceeds the required capacity.

7.6.4 No reverse grade should be allowed

7.6.5 Constructed grade should not deviate from planned grade by more than 15% of the internal diameter for drain sizes of 200 mm or less, or 10% of the internal diameter for diameters greater than 200 mm. These deviations are allowable, provided they are gradual over a distance of not less than 10 m and do not occur both above and below grade in any 30 m length of drain.

7.7 Laying Pipe — General

7.7.1 The method of installation must be compatible with the drainage system design and the existing soil conditions.

7.7.2 Pipe are to be laid to a true line and gradient on a firm bed, free from loose soil. Pipe are not to be laid on soil backfill or in slurry and are to be securely positioned to avoid displacement before backfilling the trench.

7.7.3 The inside of the drain pipe should be kept clean during construction. All soil and debris should be removed before additional pipe is laid.

7.7.4 Corrrugated plastic drain tubing is affected by temperature.

.1 At colder temperatures, plastic tubing stiffness increases and flexibility decreases; care must be taken when rolls are uncoiled.
.2 At very warm temperatures plastic tubing may deflect excessively; care must be taken when handling under such conditions.

7.7.5 Plastic tubing should not be stretched by more than 7% of its normal length.

7.7.6 In all soils the opening between clay or concrete tile should be wide enough to permit entry of the design flow but small enough to prevent entry of soil.

.1 The maximum joint spacing should be 3 mm except where special conditions indicate a wider spacing.
.2 Where joint spaces between adjacent drain tiles exceed those in 7.7.6.1 as on the outer side of a curved drain, joints should be covered with a protective material.
.3 Perforated drain pipe should be laid with the greatest number of perforations closest to the bottom of the drain; or, the drain should be deeper.

7.7.7 When rock is encountered at grade level, the trench should be excavated approximately 75 mm below grade level and filled to the planned grade as described in paragraph 7.7.8.

7.7.8 When the trench is excavated below design grade it should be filled to grade with small gravel or well pulverized soil tamped sufficiently to provide a firm foundation for the pipe.

7.7.9 Directional changes in plastic tubing can be made without the use of fittings, provided the center-line radius of the bend is not less than five times the tubing diameter.

7.8 Laying Pipe — Open Trench Installation

7.8.1 Drain trenches are to be cut to the specified depth, true to line and gradient and the trench bottom shaped so as to bed, fit and secure the drain pipe.

.1 Construction of the trench should normally start at the outlet and proceed upgrade.

7.8.2 The width of the trench measured at the top of the pipe should permit drain pipe to be laid with sufficient clearance between the wall of the trench and the pipe that blinding material will fill the space under the haunch of the pipe and provide adequate lateral support for the drain pipe

.1 The minimum clearance on each side of the pipe should be 75 mm.
.2 Special precautions may be required to protect pipe against failure by deflection when laid in wide trenches. (See 2.15.8)

7.8.3 Drain tubing must be installed so that surface and earth loads do not deflect the tubing by more than 20% of its nominal diameter.

7.8.4 A suitable plug must be provided at the upstream end of each pipe to prevent entry of soil into the drain.

7.9 Laying Pipe — Plow Installation

7.9.1 Drainage plow equipment should construct a smooth bottomed opening in the soil, and maintain the opening until the flexible tubing has been properly installed.

.1 The size of opening in the soil should conform closely to the outside diameter of the tubing.

7.9.2 Pipe must be protected from deformation and from floating in wet trenches until it has been properly laid and blinded.

7.10 Construction in Non-cohesive Soils

7.10.1 When non-cohesive soils are encountered, special construction features are required depending upon the type and conditions of the soil. Non-cohesive soils include fine sand with possibly some silt.

7.10.2 Where the trench wall is unstable or fluid soil conditions exist in a saturated silt or sand the pipe may fail to maintain alignment by caving of the trench sidewalls and misalignment of pipe. Floating of tubing may occur. A means must be provided to protect the pipe until the drain has been properly laid and blinded.

7.10.3 Where the trench bottom is unstable such as in fine sandy soil extreme care must be taken to keep sediment from entering the drain and to provide a firm foundation for the pipe.

7.11 Existing Drains

7.11.1 Existing drains which are satisfactory are to be directly connected to the new system.

7.11.2 Unless superceded by the new drains, older drains which might carry water may be indirectly connected to the new drain with permeable fill carried up or down to the level of the old drains.

7.12 Connections

7.12.1 Lateral drain pipes should connect with main drain pipes so that their center lines intersect.

7.12.2 Drains carrying sewage or farmstead wastes shall not be connected to the drainage system.

7.12.3 Manufactured "T", "Y", or elbow fittings should be used for connections at the junction of two drains.

.1 Plastic tubing connections to rigid drain tile should be made with manufactured plastic adaptors.
.2 Plastic tubing connections to plastic tubing should be made with manufactured plastic fittings.
.3 Each connection should be made with a specially manufactured connector, except when silt traps and inspection holes are provided at the location.

7.12.4 All fittings must be compatible with the pipe used.

7.12.5 Where lengths of plastic tubing are to be joined, the ends should be cut square and all ragged or burred edges removed. A plastic coupling should be used to secure the ends of the tubing in proper alignment and secured to prevent the joint from separating during installation.

7.12.6 Lateral drains, connected to main drains through cutting a hole in the drain wall, must not protrude into the main drain and obstruct the flow of water.

7.13 Connections to Municipal Drains

7.13.1 Each connection to a closed municipal drain must be approved by the local municipality responsible for the drain. (Reference: The Drainage Act. RSO 1980. s.66.)

7.13.2 Lateral drains should not be directly connected to a municipal drain, except through a sub main.

7.13.3 Any connection to a municipal drain must not obstruct the flow of water in the drain.

7.13.4 Pea stone backfill should be used around connections for structural support.

7.14 Filling the Trench

7.14.1 There may be a requirement to inspect the drain prior to blinding and/or backfilling.

.1 Any required drain pipe protection material such as filters or envelopes, must be installed before blinding.

7.14.2 Drain pipe should be blinded by placing selected material not more than 40 mm in size, preferably top soil, where ochre is not suspected, around the pipe to a minimum depth of 75 mm above the top of the pipe.

.1 Open trenches should be blinded by the end of each day.
.2 Plastic tubing should be blinded before being backfilled where bulk dumping of backfill into the trench is practised.
.3 Automatic blinding and backfilling in one operation can be used where the soil is suitable.
.4 Where the drain pipe may be subject to frost before being backfilled, the minimum depth of blinding should be 150 mm.
.5 Plastic drain tubing should be blinded immediately after installation to hold it in position on planned grade and alignment, and for protection of the tubing during backfilling.
.6 Compaction of the bedding and blinding material along the side walls of the pipe is beneficial for pipe diameters over 250 mm.
.7 Stones in the blinding material should not contact the drain pipe.
.8 On steep grades, or where the topsoil contains fine sand; loam or clay soil (if available from the sides of the trench) should be used as blinding material.

7.14.3 Trenches should be carefully backfilled with excavated material placed in such a way that the pipes are not damaged or displaced.

.1 At the end of each day's work the exposed end of the drain line should be covered to prevent entry of debris or sediment in the event of rain.
.1 The fill should be firm but not compacted so much that it prevents the passage of water to the pipe.
.3 All trenches should be filled to a level sufficiently above the surface of the ground to allow for settlement.
.4 Backfilled trenches should not be compressed.

7.15 Site Clean-Up

7.15.1 Surplus soil which is not of an injurious nature should be spread over the surrounding field. Material such as large stones, roots, etc., likely to damage implements or livestock, or of a size and character abnormal to material found on the surface of the field, should be removed.

7.15.2 The contractor should arrange to remove surplus pipe material, bands and ties, wood, glass, metal cans, and containers and other trash from the work area as agreed with the owner.

7.15.3 Fencing and other farm property should be repaired or replaced as agreed with the owner.

7.16 Inspection

7.16.1 Inspection(s) should be made during construction to ensure conformance with plans and specifications.

7.16.2 For inspection purposes, during the progress of the work and upon completion, the contractor shall provide such equipment that may be required for the inspection.

.1 Inspection pits should be excavated at selected points, preferably one or two per hectare. Additional pits may be required if the installation is faulty.
.2 Other means adopted by the contractor to demonstrate that the pipes are being laid to proper line and grade may be accepted in appropriate cases.

7.16.3 The following items should be inspected:
.1 Quality of pipe, (Sec. 6)
.2 Drain location, (Sec. 7.5)
.3 Pipe depth and grading, (Sec. 2.16 and 7.6)
.4 Trench width at top of pipe, (Sec. 7.8.2)
.5 Joint spacing and alignment of drain tile, (Sec. 7.7.6)
.6 Laying pipe, (Sec. 7.7—7.9)
.7 Connections, (Sec. 7.12)
.8 Blinding, (Sec. 7.14.2)
.9 Backfilling, (Sec. 7.14.3)
.10 Filter, envelope, stabilizing materials and placement, (Sec. 6.6)
.11 Outfalls, (Sec. 3.5)
.12 Auxiliary structures, (Sec. 3.0)
.13 Recording of alterations to the original plan, (Sec. 2.8.3).

7.16.4 If a drain is not constructed to the specifications, a completely new length of drain pipe should be laid with no attempt at remedial measures.

7.17 Outfall Structures

7.17.1. Drains that discharge into a ditch should be protected by a length of continuous rigid, non-perforated end pipe. (See 3.5)
.1 The end pipe should be installed as soon as the trench is constructed.
.2 Diameter of the end pipe should be as shown in Table VII.
.3 A grate should be attached to the end pipe at the time of installation; grate openings should not exceed 25 mm.
.4 The outfall should be a minimum of 300 mm above normal water level and should extend beyond the toe of the slope.
.5 Erosion at the outfall must be controlled.
.6 Backfill at the outfall should be placed in 75 mm layers and tamped well for a distance of 5 m from the outfall to the same density as the surrounding soil.
.7 The joint between drain pipe and end pipe should be securely sealed.
.8 A subsurface drain should be offset from the center line of a surface watercourse by one-third the width of the watercourse.
.9 Geotextiles should be placed under bank erosion control materials for drainage and stability.
.10 Where a surface watercourse must enter the ditch at the same location as a subsurface drain, an erosion-control structure should be installed.
.11 In areas where fine sand or iron compounds may enter a drain it is preferable that each drain have an individual outfall.

8.0 OUTLETS

8.1 Existing Subsurface Drains

8.1.1 Careful examinations of an existing subsurface drain is necessary if it is to be used as an outlet for a drainage system. It should be functioning properly and free from defects which may cause it to fail. It should have a sufficient capacity to carry the added flow from the proposed drainage system, and should be deep enough to allow all drains in the new system to be installed at their optimum depth.

8.2 Open Ditches

8.2.1 For Small Areas When the drainage area is less than 200 ha, and the ditch-bottom slope is greater than 0.05 per cent, open ditches may provide an adequate outlet for surface and subsurface drainage if the following recommendations are observed:

.1 There should be a minimum distance of 300 mm (if available) between the bottom of the tile outfall and the normal water level.
.2 This clearance should be increased to 450 mm if the ditch is in soil subject to erosion and deposition.
.3 Minimum bottom width of the ditch should be 1 m.
.4 Minimum side slopes for unprotected banks should be:

Soil Materials	Minimum Side Slope Ratio (vertical: horizontal)
Peat	1:1
Clayey (greater than 35% clay)	1:1.5
Loamy (10-35% clay)	1:2
Sandy or silty (less than 10% clay)	1:3
Clay of marine origin and/or banded with sand or silt (subject to low stability when saturated)	1:4
Sandy or silty with high water table and/or lateral seepage	1:4

.5 Design for as uniform a cross-section as possible.
.6 Review existing channels in similar material to verify the stability of a selected side slope ratio.
.7 When banks are submerged the side slope ratio should be increased. Side slopes of an open ditch should not be steeper than the angle of repose of the soil through which the ditch passes.
.8 Note: ditches of small section need frequent cleaning.

8.2.2 For Large Areas Open ditches which serve as outlets for large areas should be individually designed for flow velocity and capacity.

8.3 Pump Outlets

8.3.1 A pumped outlet should be considered instead of a long, costly drain or a deep outlet ditch. A pump may also be used on individual farms to drain small, isolated areas which cannot be drained by gravity. Usually a farmer's richest land is the lowest.

8.3.2 The subsurface drainage system is designed as outlined in Section 2 and the main drain is connected into a sump, or a storage ditch. A pump lifts the water to a gravity outlet.

8.3.3 The pump is usually a self-priming submersible sump pump which has the advantages of high capacity and low cost. Required pump capacity can be determined from Table X. The pump lift should not exceed 3 m. Pump selection is made on the basis of pump capacity and lift.

8.3.4 An electric motor, connected to the pump directly, or by V-belts, will be most satisfactory where electric power is available. Automatic operation is desirable, and the motor can be started and stopped by a float-operated switch or electrode controls located at selected water levels.

8.3.5 Manual-control pumps have a motor powered by gasoline or diesel fuel or by tractor power-take-off. They should be designed with storage capacity that requires not more than two starts per day.

8.3.6 Figure 16 shows a typical drainage pump with storage sump utilizing a submersible sump pump for small areas and for subsurface drainage. Figure 17 shows a typical propeller type drainage pump with storage sump where water is from subsurface drainage.

8.3.7 In silty and sandy soils it is not advisable to use the subsurface drain as part of the pumped storage as it may cause failure due to soil instability. The stop level should be below the outfall of the inlet drain.

8.3.8 For subsurface drainage a storage sump should be used to minimize the number of off-on cycles of the pump and can be constructed from corrugated steel. Pressure treated wood or poured concrete may also be used. A circular form is best.

8.3.9 When a ditch is used for storage, it should be deepened at the pump to provide adequate depth of pump submergence. In Figures 16 and 17, the depth (D) to be removed at each operation can be varied, but is usually 600 mm for sump storage with automatic operation, and 300-400 mm for ditch storage with manual operation. Minimum storage requirements are given in Table X. Where more storage than is shown in Table X is available for manual-control pumps, pump capacity can be reduced.

8.3.10 When surface water is to be pumped additional design information on rainfall rate and recurrence interval, crop damage, and surface runoff must be considered.

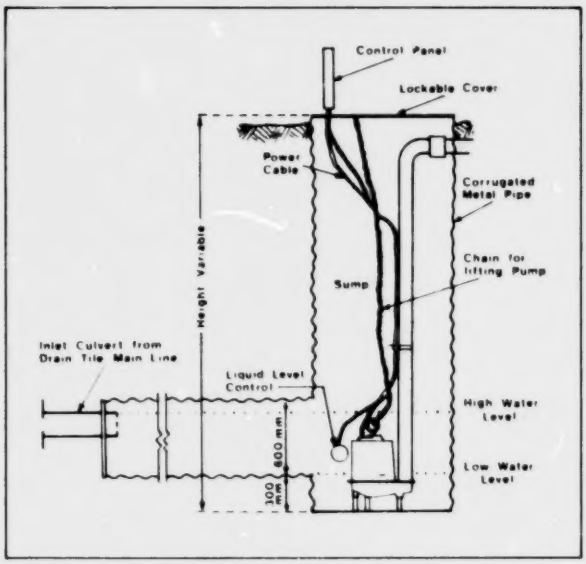

Figure 16. Typical submersible drainage pump

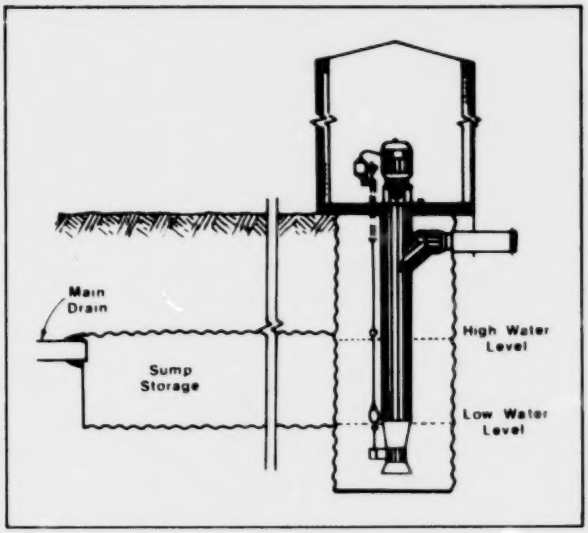

Figure 17. Typical propeller type drainage pump

TABLE X

DESIGN VALUES FOR PUMP DRAINAGE

DRAINAGE AREA	PUMP AND MOTOR CAPACITY				MINIMUM STORAGE VOLUME REQUIRED		
	Tile Drain Discharge		Surface & Tile Drain Discharge		Automatic Operation		Manual Operation
	Pump	Motor	Pump	Motor	Tile Drain Discharge	Surface and Tile Drain Discharge	Surface and Tile Drain Discharge
(ha)	(L/s)	(kW)	(L/s)	(kW)	(m^3)	(m^3)	(m^3)
4	10	1.1	11	1.1	1.0	1.2	200
8	20	1.1	23	1.1	1.5	1.8	400
16	30	1.1	38	1.5	2.8	3.4	600
24	40	1.5	45	2.2	4.2	5.0	800
32	50	2.2	60	3.7	5.7	6.8	1000
40	60	3.7	75	3.7	9.5	11.5	1200
60	90	5.5	115	5.5	14.0	16.8	1800
80	125	5.5	150	7.4	18.9	22.7	2500

* *Based upon a 12 mm drainage coefficient*
** *Based upon a 2.5 m average pumping lift, efficiency 50%*
1 L/s = 0.001 m^3/s

APPENDIX A

DESIGN CODE DETAIL (2.5.1)

TABLE A-1 — GENERALIZED PROFILE DESCRIPTIONS

Drainage Group	General Description	Generalized Texture and Structure "A" Horizons	"B" Horizons	"C" Horizons	Families Included
S1	Overall fine texture. Poor development, soil becomes more compact with depth	Fine to medium texture. C,SiC or SiCL. Granular structure	Fine texture, C. Coarse blocky structure	Fine texture, C Medium to coarse, blocky, to massive structure	Clyde, Haileybury, Lincoln, Minesing, New Liskeard, Renfrew, Rideau, South Bay
S2	Overall medium texture and well structured. Soil becomes more compact with depth. Free water saturation at depths less than 1 metre on parent material	Medium texture, L, SiL, CL or SiCL. Platy or granular structure	Fine to medium texture C, SiCL, CL. Medium to coarse, subgranular to angular blocky structure	Fine to medium texture, C, SiC, SiCL, CL. Medium to coarse, blocky, prismatic to massive structure	Beverly, Brantford, Brookston, Cane, Conover, Dorking, Eldershe, Haldimand, Huron, Miami, Ontario, Perth, Renfrew, St. Clements, Wellesley, Wilmot
S3	Overall medium to coarse texture. Sola are deeper than S 2. Free water saturation at depths less than 1 metre on II C	Medium to coarse texture, L, SL, LS or S, single grain or fine platy structure	Medium to coarse texture, SCL, L, SL, S. Platy or fine to coarse subgranular blocky structure	Fine to medium texture, C, SiC, SiCL, CL, SCL, SiL. Coarse angular blocky structure	Allendale, Bainsville, Berrien, Bookton, Bucke, Honeywood, Maplewood, Mountain, Nipissing, Tuscola
S4	Overall medium to coarse texture, with fine textured "B" horizon that may impede internal drainage	Medium to coarse texture, SCL, SiL, L, SL, LS, S Medium granular structure	Medium to coarse texture, SCL, SiC, SiCL, SCL Medium subgranular to medium angular blocky structure	Medium texture, L, CL, SiL, SCL, SiCL. Weak prismatic to blocky structure	Boomer, Earlton, Evanturel. Some northern Ontario Gray Luvisols will be in this group
S5	A bog like depressional soil. The surface layer is organic	Organic	Fine to medium, sand	Fine texture, C Massive	Belmeade
S6	Shallow soil over bedrock	Medium to coarse texture Medium structure	Fine to medium texture Medium subangular to medium angular blocky structure		Ameliasburg, Bastard, Brooke, Farmington, Franktown, Gerow, Lockport, Shashawandah, Trafalgar, Tweed
G1	Soils developed on loam, silt loam and stratified by ponding. Seasonal free water saturation in relation to perched groundwater	Medium texture, L, SiL. Granular structure	Medium texture, S, SL. Single grain to medium subangular blocky structure	Medium texture, L, SiL. May be stratified. Coarse subangular blocky to massive structure	Colwood, Conestoga, Coutts, Freeport, Grand, Grenville, Guelph, Howland, Killean, London, Lyons, Macton, Magnetawan, Mannheim, Maryhill, Matilda, Moose, Osprey, Otonabee, Vasey, Wabi, Woolwich.
G2	Outwash sands, more than 1 metre deep over clay till, or lacustrine clay. Seasonal free water saturation in relation to perched groundwater	Coarse texture, S, SI Granular structure	Coarse texture, S, SL. Single grain to medium subangular blocky structure	Coarse texture, S, SL. Single grained loose structure.	Berriedale, Brady, Elmira, Fox, Granby, Kenabeek, Rubicon
G3	Deep coarse textured soils with seasonal free water saturation in relation to regional groundwater.	Medium to coarse texture, L, SL. Granular structure	Medium to coarse texture, L, S L. Granular structure	Sand or gravel possibly over bedrock	Alliston, Ayr, Brisbane, Burford, Burpee, Donald, Dumfries, Eastport, Floradale, Fort, Gwillimbury, Hawkesville, Haysville, Heidelburg, Hendrie, Hespeler, Kirkland, Lisbon, Pontypool, Preston, Sargent, Springvale, St. Peter, Sullivan, Tioga, Wendigo

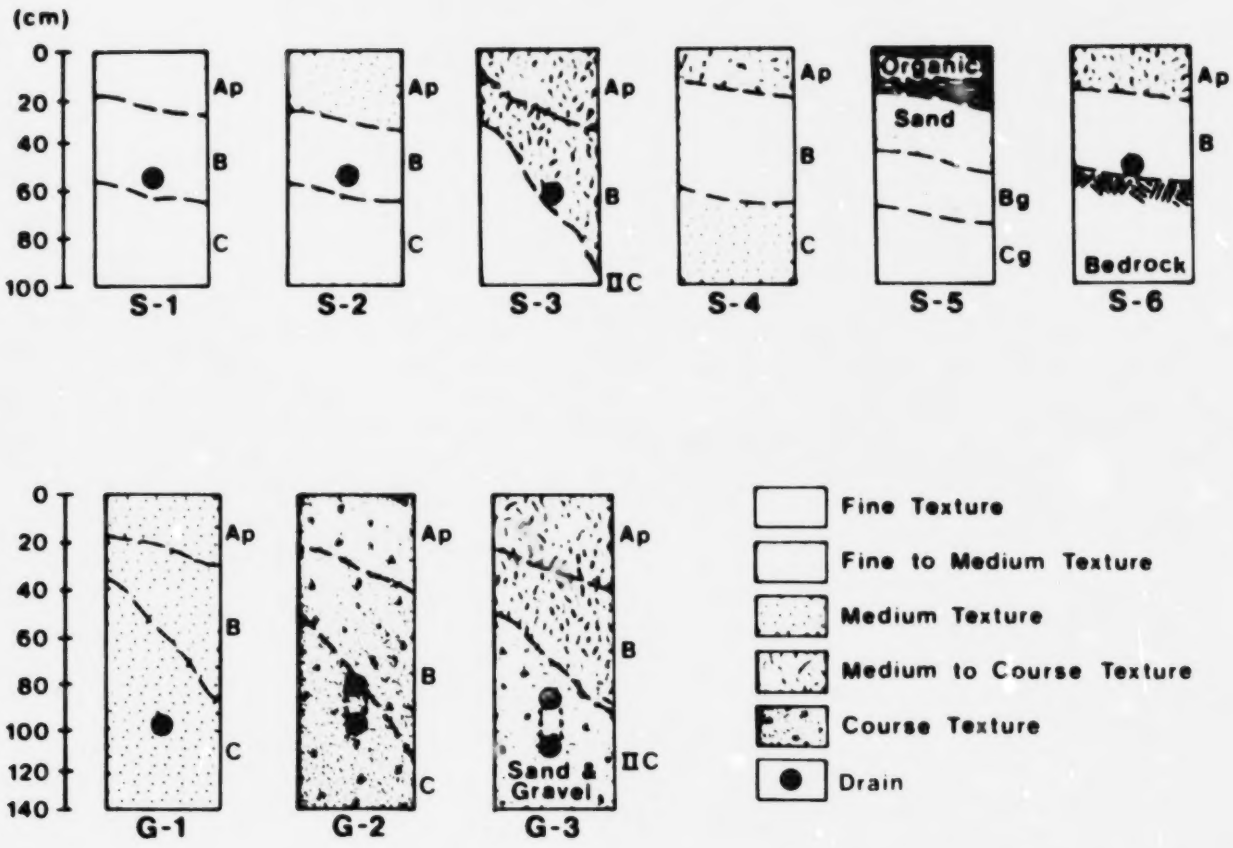

Figure A-1. Generalized soil profiles of drainage code (See 2.5)

TABLE A-2

HYDRAULIC CONDUCTIVITY CLASS

Drainage Class			USDA Hydrologic Class	Hydraulic Conductivity K		
				cm/h	m/s	m/d
High	R	H2	A	>50	1.4×10^{-4}	12
	VR	H1	A	15-50	4.6×10^{-5}	4
Medium	MR	M3	B	5-15	1.2×10^{-5}	1
	M	M2	B	1.5-5	4.6×10^{-6}	4×10^{-4}
	MS	M1	C	0.5-1.5	1.2×10^{-6}	1×10^{-1}
Low	S	L3	C	0.15-0.5	4.6×10^{-7}	4×10^{-2}
	VS	L2	D	0.05-0.15	4.6×10^{-8}	4×10^{-3}
	ES	L1	D	<0.05		

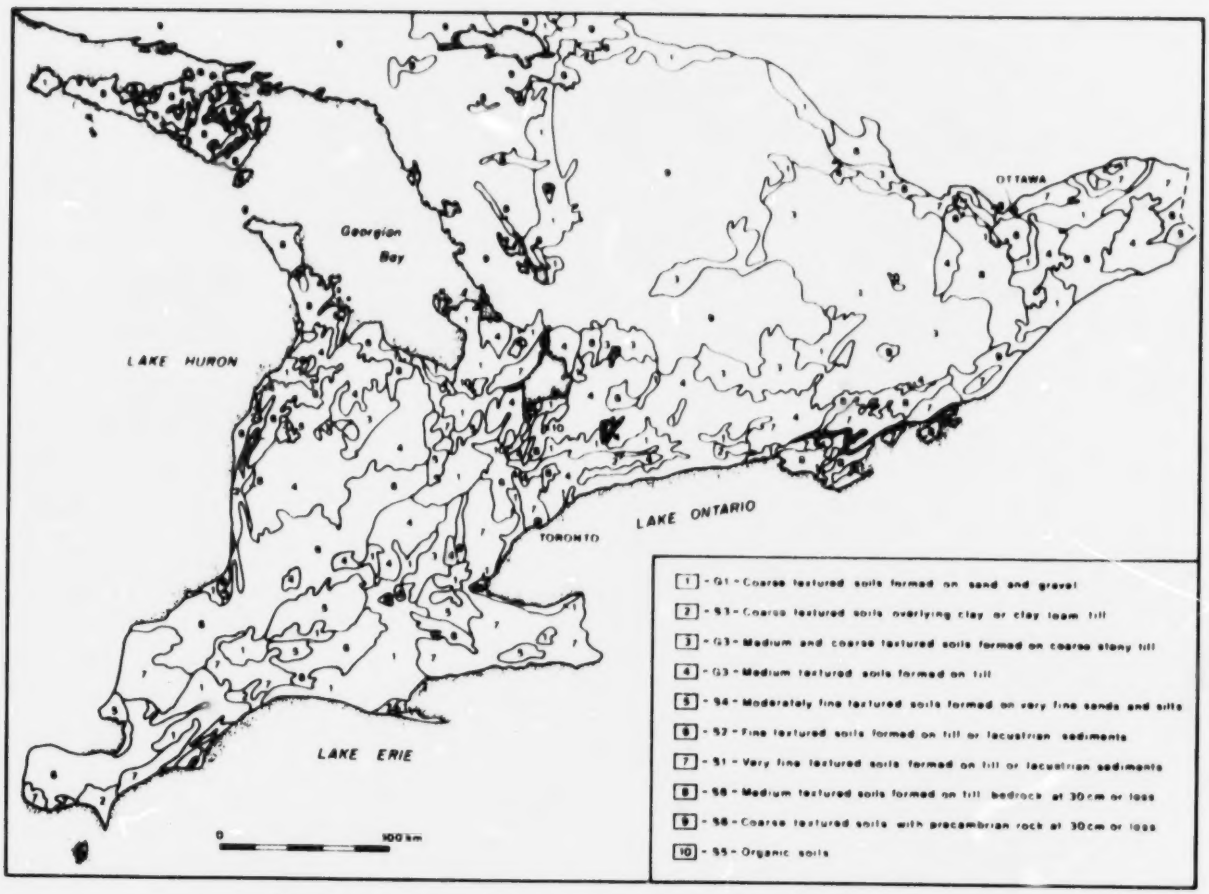
OTTAWA
Georgian Bay
LAKE HURON
TORONTO
LAKE ONTARIO
LAKE ERIE
0
100 km
1 - G1 - Coarse textured soils formed on sand and gravel
2 - G2 - Coarse textured soils overlying clay or clay loam till
3 - G3 - Medium and coarse textured soils formed on coarse stony till
4 - G3 - Medium textured soils formed on till
5 - M4 - Moderately fine textured soils formed on very fine sands and silts
6 - M2 - Fine textured soils formed on till or lacustrian sediments
7 - M1 - Very fine textured soils formed on till or lacustrian sediments
8 - M6 - Medium textured soils formed on till bedrock at 30cm or less
9 - M6 - Coarse textured soils with precambrian rock at 30cm or less
10 - O5 - Organic soils

Figure A-2. General distribution of drainage code soil profiles

SURFACE EXPRESSION

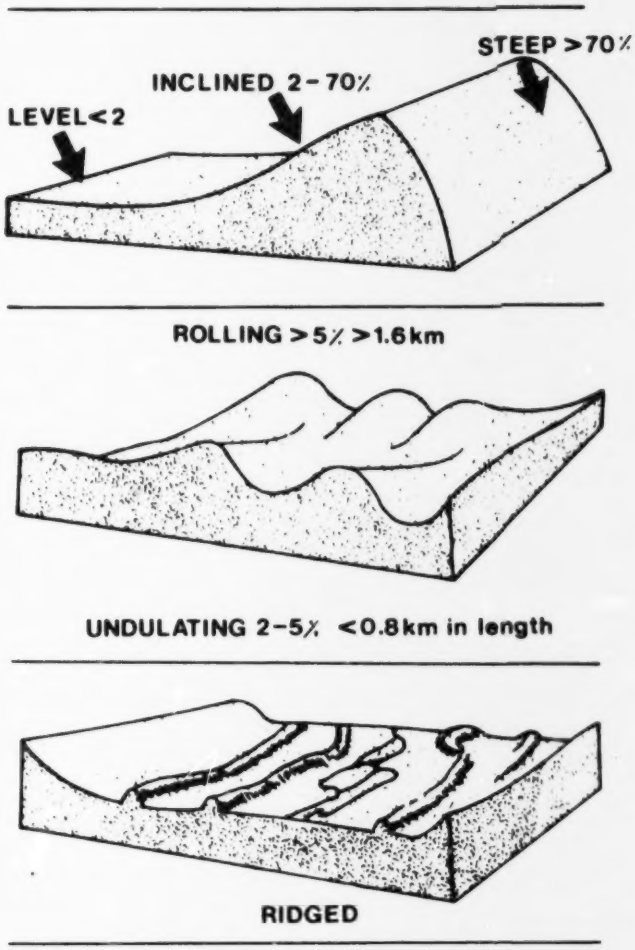

Figure A-3. Sketches of landform and slope

TABLE A-3 — NATURAL DRAINAGE CLASSES[1]

Code Symbol	Description
W	**Well drained** — The soil moisture content does not normally exceed field capacity in any horizon (except possibly the C) for a significant part of the year. Soils are usually free from mottling in the upper metre but may be mottled below this depth. B horizons, if present, are reddish, brownish, or yellowish.
M	**Moderately well drained** — The soil moisture in excess of field capacity remains for a small but significant period of the year. Soils are commonly mottled in the lower B and C horizons or below a depth of 750 mm. The Ae horizon, if present, may be faintly mottled in fine-textured soils and in medium-textured soils that have a slowly permeable layer below the solum. In grassland soils the B and C horizons may be only faintly mottled and the A horizon may be relatively thick and dark.
I	**Imperfectly drained** — The soil moisture in excess of field capacity remains in subsurface horizons for moderately long periods during the year. Soils are commonly mottled in the B and C horizons; an Ae horizon, if present, may be mottled. The matrix generally has a lower chroma than in the well-drained soil on similar parent material.
P	**Poorly drained** — The soil moisture in excess of field capacity remains in all horizons for a large part of the year. The soils are usually very strongly gleyed. Except in high-chroma parent materials the B, if present, and upper C horizons usually have matrix colors of low chroma. Faint mottling may occur throughout.
V	**Very poorly drained** — Free water remains at or within 300 mm of the surface most of the year. The soils are usually very strongly gleyed. Subsurface horizons usually are of low chroma and yellowish to bluish hues. Mottling may be present but at depth in the profile. Very poorly drained soils usually have a mucky of peaty surface horizon.

[1] *Descriptions are taken from p 220-221, "The system of Soil Classification For Canada", Agriculture Canada, 1972.*

TABLE A-4 — LANDFORM CLASSES

Code Symbol	Landform
A	Level
B	Level, dissected
C	Level to inclined, dissected
D	Level, complex
E	Level terraced
F	Level, midslope terraced
G	Level to inclined
H	Level to undulating
I	Level to undulating, midslope
J	Level to undulating, midslope terraced
K	Undulating
L	Undulating, dissected midslope
M	Undulating midslope
N	Undulating ridged
O	Inclined
P	Inclined midslope
Q	Inclined to undulating, terraced
R	Inclined dissected
S	Inclined to hummocky
T	Undulating to rolling
U	Undulating to rolling, dissected
V	Hummocky
W	Hummocky ridged
X	Rolling
Y	Rolling, dissected
Z	Rolling, ridged
a	Terraced dissected
b	Undulating to inclined, midslope, complex dissected

TABLE A-5 — SLOPE CLASSES

Code Symbol	Slope Range	Definition	Canada System Soil Classification Slope Classes
1	0-.5%	Level	1
2	0-2%	Level to nearly level	1 and 2
3	.5-2%	Nearly level	2
4	.5-5%	Nearly level to very gentle slopes	2 and 3
5	2-5%	Very gentle slopes	3
6	2-9%	Very gentle to gentle slopes	3 and 4
7	2-15%	Very gentle to moderate slopes	3, 4 and 5
8	6-15%	Gentle to moderate slopes	4 and 5
9	10-30%	Moderate to strong slopes	5 and 6

TABLE A-6 — SOIL CAPABILITY CLASS

(2.5.2)
DESCRIPTIONS FOR AGRICULTURE

CLASS 1 Soils in this class have no significant limitations in use for crops.

CLASS 2 Soils in this class have moderate limitations that restrict the range of crops or require moderate conservation practices.

CLASS 3 Soils in this class have moderately severe limitations that restrict the range of crops or require special conservation practices or both.

CLASS 4 Soils in this class have severe limitations that restrict the range of crops or require special conservation practices.

CLASS 5 Soils in this class have very severe limitations that restrict their capability to producing perennial forage crops, and improvement practices are feasible.

CLASS 6 Soils in this class are capable only of producing perennial forage crops, and improved practices are not feasible.

CLASS 7 Soils in this class have no capability for arable culture or permanent pasture.

Capability Subclasses

Subclasses are divisions within classes that have the same kind of limitations for agricultural use. Thirteen different kinds of limitations are recognized at the subclass level. A brief discussion of these subclasses and their designation on maps follows.

Undesirable soil structure and/or low permeability (D): This subclass is used for soils difficult to till, or which absorb water very slowly, or in which the depth of the rooting zone is restricted by conditions other than a high water table or consolidated bedrock.

Inundation by streams or lakes (I): This subclass includes soils subjected to inundation causing crop damage or restricting agricultural use.

Moisture limitation (M): This subclass consists of soils where crops are adversely affected by drought owing to inherent soil characteristics. They are usually soils with low water-holding capacity.

Stoniness (P): This subclass is made up of soils sufficiently stony to significantly hinder tillage, planting, and harvesting operations. Stony soils are usually less productive than comparable non-stony soils.

Consolidated bedrock (R): This subclass includes soils where the presence of bedrock near the surface restricts their agricultural use. Consolidated bedrock at depths greater than 3 feet from the surface is not considered as a limitation, except on irrigated lands where a greater depth of soil is desirable.

Excess water (W): Subclass W is made up of soils where excess water, other than that brought about by inundation is a limitation to their use for agriculture. Excess water may result from inadequate soil drainage, a high water table, seepage or runoff from surrounding areas.

See OMAF Factsheet, *Soil Capability Classification for Agriculture*, Agdex 524.

APPENDIX B

CALCULATION OF DRAIN SPACING

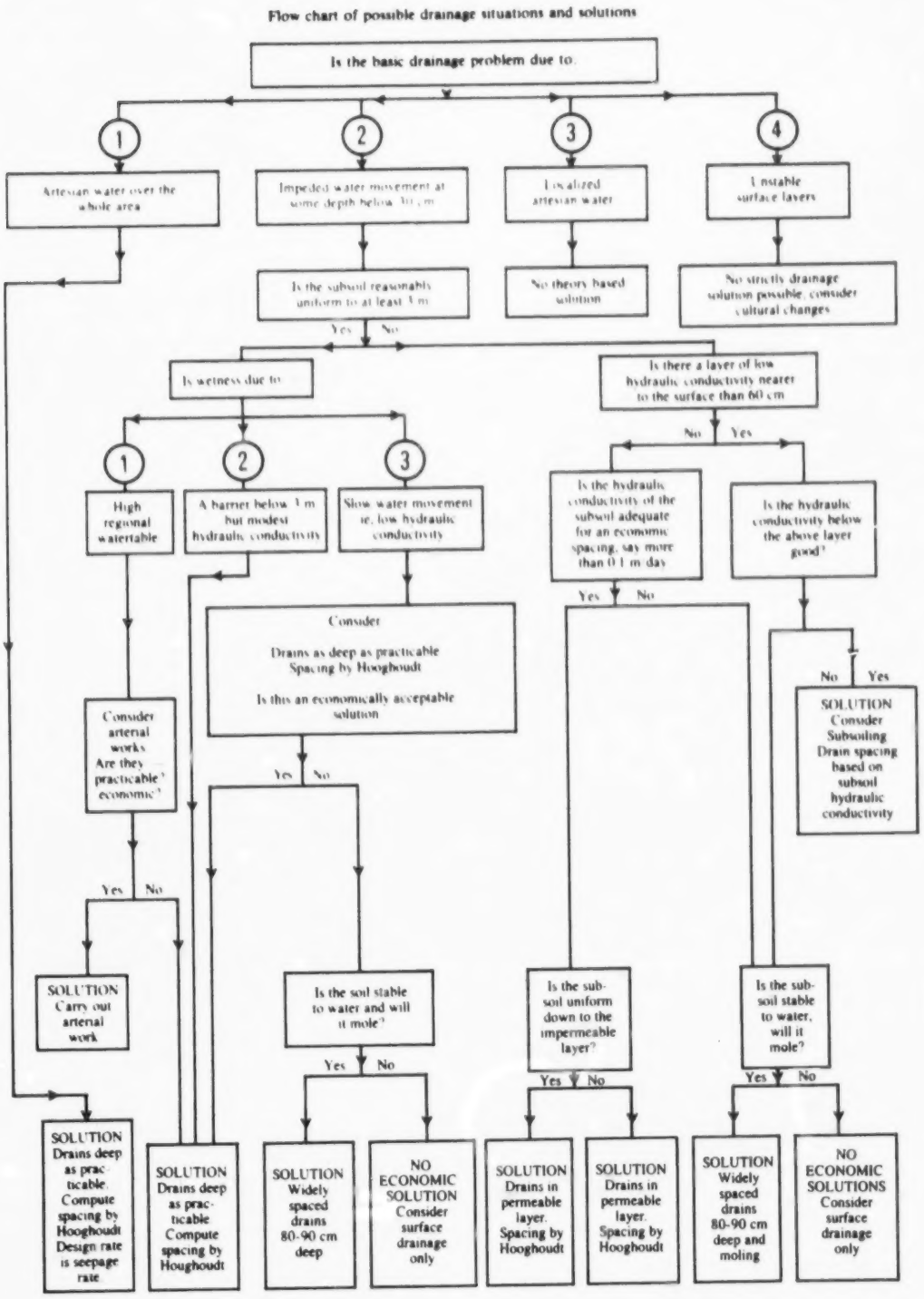

Figure B-1. A flow chart showing the situation where a scientifically based drainage design is possible and the type of design approach used.

Hooghoudt Drain Spacing Equation

The steady state drain spacing formula, due to Hooghoudt (1940), is presented here because it is the most widely accepted and often used in practice. Hooghoudt states:

$$S^2 = (4 K_2 d_e m + 2K_1 m^2)/R$$

where

S = drain spacing, m

K_1 = hydraulic conductivity of the layer above the drains, m/d

K_2 = hydraulic conductivity of the layer below the drains, m/d

d_e = equivalent depth of conducting soil below drains, or effective depth of flow dependent on depth to impermeable layer, drain spacing, and drain diameter, m

m = mid-spacing watertable height, m

R = drainage rate, m/d

The hydraulic conductivity, K_1 and K_2, should be measured in the field. When direct measurements are not available these values may be estimated from Figure B-2.

It will be seen that as S affects d_e the equation is not directly solvable and trial and error solutions must be used. However, calculations are less tedious if a spacing S is assumed and the required hydraulic conductivity, K_2 is calculated. Working in this way, a two layer situation can only be tackled if one assumes that K_1 and K_2 bear some relation to one another; i.e. $K_1 = 2K_2$, $K_1 = 5K_2$, etc. In this form the equation is:—

$$K_2 = (RS^2)/(8 d_e m + 4n m^2)$$

where n = the numerical relationship between K_1 and K_2.

The equivalent depth, d_e, for a selected drain spacing and depth to impermeable layer, can be estimated from Figure B-3.

In Figure B-4 the drainage rate, R, has been assumed to be 10 mm/d (cereal crop), because this seems to have reasonable application in Ontario. Strictly, one should vary the design criteria to suit the crop and climatic conditions of the area. Present knowledge does not allow this to be done with any precision. In the calculations, the mid-spacing watertable height between drains, m, has been chosen as 50 cm. This may be interpreted as 50 cm of freeboard, or unsaturated soil, with a drain depth of 1 m, or, 30 cm and a drain depth of 80 cm, or any combination. A spacing of 10 m has been chosen as the minimum likely to be economic for most cases.

Figure B-4 illustrates the way in which hydraulic conductivity and drain spacing are related for a number of positions of the impermeable layer. The impermeable layer is taken as a layer having less than 1/10 of the hydraulic conductivity of the layer above it. Note that the position of the impermeable layer is critical when it is close to drain depth, but decreases in importance as the depth of the layer increases.

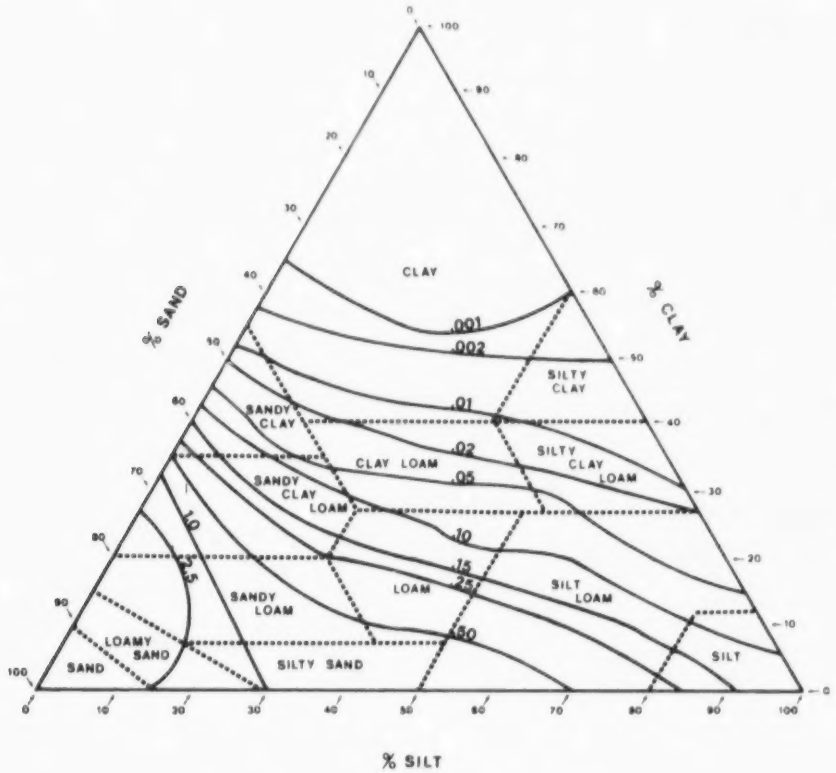

Figure B-2. Estimated relationship between soil texture and saturated hydraulic conductivity
(Values shown are m/d)

Note: This chart should only be used when actual field measurements are not available. Changes in soil porosity will require adjustment of these average values.

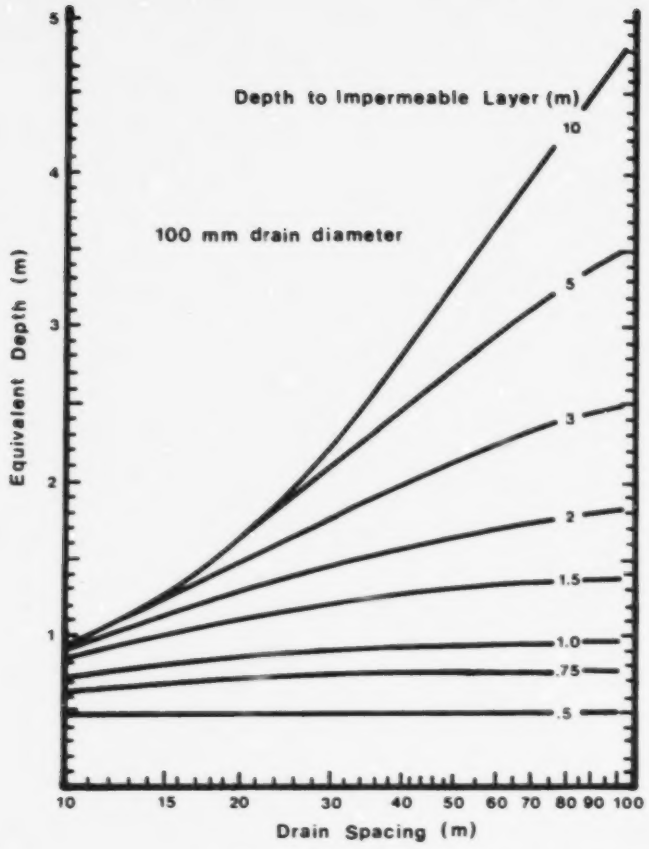

Figure B-3. Estimation of equivalent depth for a selected drain spacing

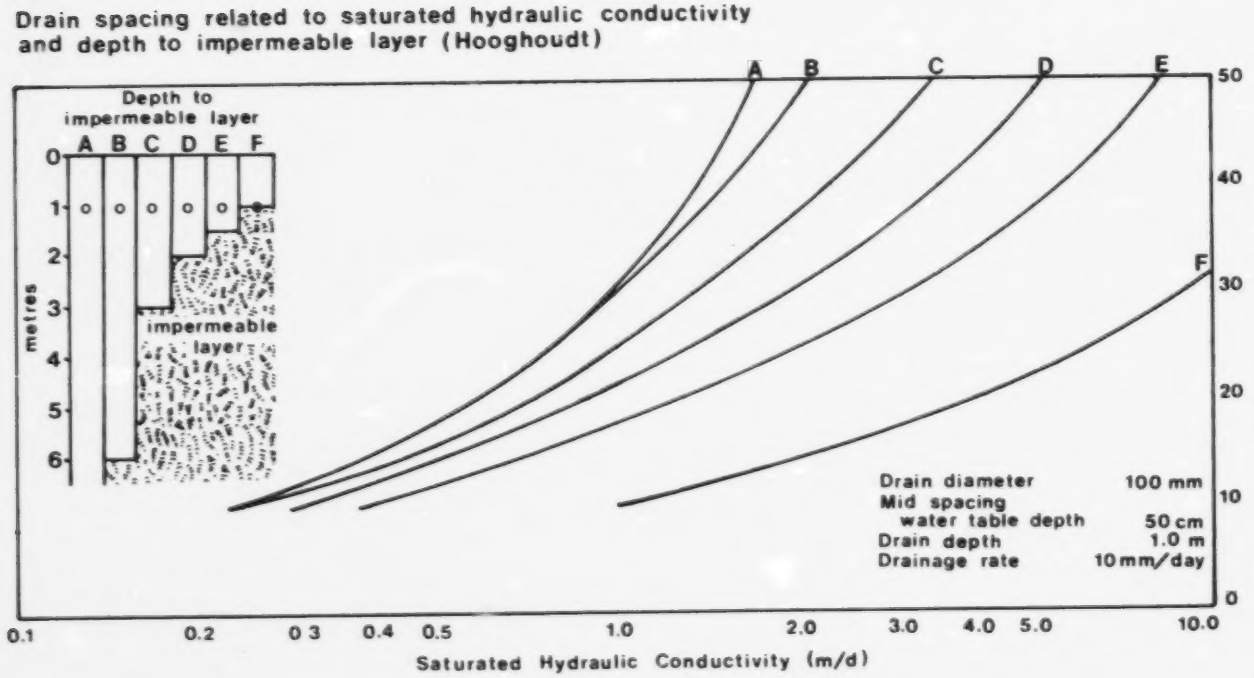

Figure B-4. General relation between saturated hydraulic conductivity and drain spacing

APPENDIX C

TABLE C-1 — LATERAL DRAIN PIPE REQUIREMENTS PER HECTARE

Lateral Spacing (m)	Pipe per hectare* (m)
6	1667
9	1111
12	833
15	667
18	556
25	400
30	333

**Main and submain drain requirements are not included.*

TABLE C-2 — METRIC MEASUREMENT CONVERSIONS

Symbol	When You Know	Multiply By	To Find	Symbol
Length				
mm	millimetres	0.039	inches	in
m	metres	3.281	feet	ft
km	kilometres	0.621	miles	mi
Area				
m^2	square metres	10.764	square feet	ft^2
km^2	square kilometres	0.394	square miles	mi^2
ha	hectares	2.471	acres	ac
Volume				
L	litres	0.264	gallons	gal (US)
L	litres	0.220	gallons	gal (Imp)
L	litres	0.001	cubic metres	m^3
Rate				
L/s	litres per second	15.850	gallons per minute	gpm (US)
L/m	litres per minute	0.264	gallons per minute	gpm (US)
m^3/s	cubic metres per second	0.028	cubic feet per second	cfs
Other				
W	watts	0.001	horsepower	hp

To convert *from* Imperial *to* Metric units *divide* by the number in column 3. For example, when you know inches, say 1.5; to find millimetres divide 1.5 ÷ .039 = 38.1 mm.

TABLE C-3 — DEFINITIONS

Backfilling	Placement of excavated soil in the trench after blinding has been completed.
Bedding	The earth foundation of the trench together with the select material around and over the drain, including envelope and filter material where used.
Blinding	Placement of select soil around a drain to prevent damage or misalignment when the trench is backfilled and to allow water to flow freely to the drain.
Coefficient of roughness	Factor expressing the frictional resistance to flow of a channel surface or a drain interior.
Connections	Fittings used to join two drain lines.
Continuous pipe	Extended length of pipe without perforations or unsealed joints.
Drain invert	The lowest part of the internal cross-section of a lined channel or pipe.
Drainage area	Area from which drainage water is collected and delivered to an outlet. Sometimes referred to as the watershed area for a particular drain.
Drainage coefficient	The depth of water, in mm to be removed from an area within 24 hours.
Drainage system	Collection of surface ditches or subsurface drains, together with structures and pumps used to collect and dispose of excess surface of subsurface water.
Equivalent depth	The equivalent depth (de) is a function of the drain spacing, drain tube radius and depth (d) to the impermeable layer below the drain centers. It is the effective flow through the soil below the drains. Hooghoudt has suggested the use of de to replace the actual depth to the impermeable barrier as a means of accounting for the physical convergence of flow lines near the drain.
Gley	Gleization in poorly drained soils involves the reduction of iron into coloured mottles and concretions. Gley layers often have increased density.
Grade or gradeline	Degree of slope of a channel or natural ground.
Impermeable layer	If the permeability of the subsoil is about one-tenth that of the surface soil it can be considered impermeable from a drainage standpoint.
Interceptor line or drain	Surface ditch or subsurface drain, or a combination of both, designed and installed to intercept several lines to keep the number of crossings at highways and similar locations to a minimum (also called collector lines).
Junction	Point of intersection of two or more surface ditches or subsurface drains.
Land grading	The shaping of the land surface by cutting, filling and smoothing to planned grades so that each row or surface slopes to a drain without ponding.
Land smoothing	Shaping the land surface with a land plane or land leveler to eliminate minor depressions and irregularities without changing the general topography. The depth of cut in this operation is generally small and limited by the kind of equipment used. Land smoothing is also the finished operation in land grading.
Lateral drain	Secondary drain that collects excess water from a field.
Main drain	Principal drain that conducts drainage water from the lateral drains and submains to an outlet.
Pumping plant	One or more pumps, power units, and appurtenances for lifting drainage water from a collecting basin to a gravity outlet.
Submain	Branch drain off the main drain which collects discharge water from lateral drains.
Subsurface drainage	The removal of excess water from below the soil surface by means of drain tile, perforated pipe, mole channels, or other devices.
Surface drainage	The diversion or orderly removal of excess water from the surface of the land by means of improved natural or constructed channels, supplemented when necessary by sloping and grading of land surfaces to these channels.
Tile	Drain pipe made of burned clay, concrete, or similar material, in short length usually laid with open joints to collect and carry excess water from the soil.
Tubing	A flexible drain pipe that gains part of its vertical soil load-carrying capacity from lateral support of the surrounding soil.
Watershed	Total land area above a given point on a stream or waterway that contributes runoff to that point.
Watertable	The upper surface of a saturated zone within the soil.